

PRODUCT APPLICATION GUIDE

A technical bulletin for engineers, contractors and students in the air movement and control industry.

Motor Application Guide for Ventilation Products

The evaluation of a fan's motor is a time consuming part of the design of air handling equipment. Selection of the proper electrical characteristics and construction features can involve factors not known to everyone. The purpose of this article is to aid in the selection of the correct motor type from an electrical and mechanical standpoint for a given application and fan type.

Understanding the material in this article will help you identify and eliminate application problems before they are encountered. When selecting a motor, make sure the fan and application are in sync with each other. For example, money is wasted when putting an expensive, special duty motor costing hundreds (or sometimes thousands) of dollars extra on a fan used in normal clean air applications. The overall benefit is not having to deal with special design requests that result in unnecessary extra expense and longer lead times.

Most often the fan manufacturer will recommend the proper standard motor for the application. If your application requires special consideration, an outline of the factors to consider in evaluating fan motor performance is included for reference. Please



refer to the Table of Contents to locate the appropriate category.

Motor applications

When selecting the proper motor for the application, there are many overlooked considerations. The two most common are:

Physical size:

Space available for motor mounting may limit selections. Many two speed and explosion resistant motors may not fit in a fan that was not originally designed for such applications, especially those selected for low cfm.

Belt drive fans vs. direct drive fans:

Selection of belt driven versus direct driven fans should involve consideration of fan sound levels, motor cost, and maintenance. The belt driven fan has pulleys, shafts, bearings, and belt(s) which contribute to cost. However, lower

Table of Contents	Page
Motor applications	1
• Motor & fan size limitations	
• Belt drive vs. direct drive	
Motor enclosures	2
• Open	
• Totally enclosed	
• Explosion resistant	
Motor types	4
• Single-phase	
• Three-phase	
• Summary chart	
Motor speed	6
• Multi-speed motors	
• Voltage and phase	
• Service factor	
Efficiency	8
• Epact	
• Insulation	
Mounting	10
Motor protection (Thermal overload)	10
Underwriters Laboratory (UL)	10
Testing at Greenheck	11
Glossary of terms	12

cost, higher speed motors are generally used. Belt driven fans are typically less efficient due to belt and bearing losses. Selection of larger, slower moving belt driven fans will generate less noise for a given application. Smaller direct drive fans will have a faster rotating wheel for the same air delivery and be more efficient, however generate more noise. Belt driven fans and very large or heavy direct driven fans require high starting torque of split-phase, capacitor-start, or three-phase motors. Direct driven motors work great where access to bearings and belts are difficult. Motors for belt driven fans are typically 1725 rpm (60 cycle), while direct drive fans have specific motor rpm's available to accommodate for no pulley adjustment. Typically, when motors are lower than 1725 rpm, they cost more, are physically larger, have longer leadtimes, and have fewer motor options available.

Motor enclosures

Many types of motor enclosures are available for all conditions from open to explosion resistant. The most common motor enclosures used with fans are open and totally enclosed. There are several different types within each enclosure. In most cases, it is best to let the fan manufacturer select within the subcategory of enclosures.

Open: Has ventilation openings which permit passage of external cooling air over and around the windings of the motor. The term "open" designates having no restriction to ventilation other than that necessitated by mechanical construction. An open dripproof (ODP) motor is where ventilating openings are constructed such that operation is not interfered with when drops of liquid or solid particles strike or enter the enclosure at any angle from 0 to 15 degrees downward from vertical. The motor must be mounted in the proper orientation for the open dripproof enclosure to function as designed.

Application: Suitable for indoor use and in relatively clean atmospheres that are fairly dry and well ventilated. They do not offer



Open drip-proof motor

protection from airborne dust or chemical vapor. Typically used on small centrifugal roof fans with the motor out of airstream where the air is clean and dry.

Totally enclosed: Prevents free exchange of air between the inside and outside of the case, but not sufficiently enclosed to be termed airtight. Totally enclosed motors are best suited for use in humid environments or dusty, contaminated atmospheres. Some totally enclosed motors are also available for the more severe applications.

Totally enclosed fan cooled (TEFC): A totally enclosed fan cooled motor that is equipped for exterior cooling by means of a fan integral to the motor but external to the enclosed parts.

Application: Used when protection from dust, moisture, rain and non-explosive atmospheres are required and inadequate airflow over the motor is provided by the device it drives. These motors are typically used on belt driven inline or duct fans.



Totally Enclosed Fan Cooled Motor

Totally enclosed air over (TEAO): A totally enclosed air over motor is not self ventilated and must be cooled by means external to the motor.

Application: These motors are used when protection is required from dust, moisture, rain, and non-explosive atmospheres. These motors are not self-cooling, so they are typically used where the driven device is a fan or blower that provides the necessary air movement over the motor for cooling. It is important that the airflow over the motor is of high enough velocity to equal or exceed the cooling offered by an integral fan. These motors are typically used on sidewall propeller fans, direct drive axial fans, and vane axial fans.

Totally enclosed special duty: Severe duty motors are always totally enclosed, three-phase, cast iron casing with Class F insulation. They are designed for use in extremely moist or chemical environments but not for hazardous locations. These are typically called marine duty or chemical duty.

A washdown duty motor is totally enclosed and built to handle high-pressure washdowns. These

motors are used in wet environments and where motors are subject to repeated washdowns.

Explosion resistant (EXP): A totally enclosed motor is designed and constructed to withstand an internal explosion of specified gases or vapors, and not allow the internal flame or explosion to escape.

When explosion resistant motors are required, there is much to consider. This is why there are so many classes, divisions, and groups. The classification of the hazard requires considerable skill and judgement, particularly to the extent of the hazardous area. Generally, these conditions are defined by the Safety Engineer or by the insurance company. Motors designed for one hazardous location are not necessarily suitable for use in another. In many cases, explosion resistant motors will not fit on the originally selected fan due to the increased size.



Explosion resistant motor

Listed below is a definition of the various classes and divisions of explosive atmospheres. The containment aspects are defined by “divisions” according to the likely concentration of the hazard. Division I is applicable to routine or periodic exposure. Division 2 refers to a hazard that is normally confined within a system or container and which would only escape in the event of some abnormal circumstance or equipment failure.

Class I locations: These are hazardous because of the presence of flammable gases or vapors in quantities to produce explosive or ignitable mixtures.

Class I, Division I locations exist where ignitable concentrations of flammable gases or vapors exist under normal conditions, or where ignitable concentrations of such gas or vapor may exist frequently, or where a breakdown might release ignitable concentrations, and may cause simultaneous electrical equipment failure.

Class I, Division 2 locations exist where flammable liquids or flammable gases are normally confined

within closed containers or systems from which they can escape only in the event of an accidental breakdown or abnormal operations.

Class II locations: These are hazardous because of the presence of combustible dust.

Class II, Division 1 locations exist where combustible dust is in the air in concentrations sufficient to produce explosives or ignitable mixtures, or where equipment or machinery failure might cause the concentration to be produced, or where the concentration might be electrically conductive.

Class II, Division 2 locations exist where combustible dust is not in sufficient concentration to produce explosive or ignitable mixtures, or dust is in suspension in the air as a result of processing or infrequent malfunctioning of equipment, and dust concentration may be ignitable by abnormal occurrences.

Class III locations: These are hazardous locations due to ignitable fibers or combustible flyings that are not in suspension in sufficient concentration to produce ignitable mixtures.

Class III, Division 1 locations exist where easily ignitable fibers or materials producing combustible flyings are being processed or used.

Class III, Division 2 locations exist where easily ignitable fibers are stored or handled.

Groups (Hazard degrees) The National Electrical Code (NEC) categorizes hazardous atmospheres and locations. Because the type and degree of hazard varies widely according to the materials encountered and their probable presence in hazardous quantities, the following methods of identification are used. Materials are “classed” as flammable vapors or gases (Class I), or as combustible dusts (Class II). Additionally, materials are “grouped” according to their relative degree of hazard with Groups C and D applicable to vapors or gases, and Groups E through G applicable to combustible dusts.

Class I, Group A: Atmospheres containing acetylene.

Class I, Group B: Atmospheres containing hydrogen or gases or vapors of equivalent hazards such as manufactured gas.

Class I, Group C: Atmospheres containing ethyl ether vapors, ethylene or cyclopropane.

Class I, Group D: Atmospheres containing gasoline, hexane, naphtha, benzene, butane, alcohol, acetone, benzyl, lacquer solvent vapors, or natural gas.

Class II, Group E: Atmospheres containing metal dust, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics.

Class II, Group F: Atmospheres containing carbon black, coal or coke dust.

Class II, Group G: Atmospheres containing flour, starch, or grain dust.

Explosion resistant equipment is not generally available for Class I, Groups A and B locations and it is necessary to isolate motors from the hazardous area.

A common misconception is that just because the class and group exist there should be suitable products (motors and other equipment) to operate in the defined environment. In the case of Class I Groups A and B, the market is limited and designs are so difficult, that most manufacturers do not make them.

Fan construction

As previously mentioned, fan applications suitable for explosion resistant motors may involve the handling of potentially explosive or flammable particles, fumes or vapors. Such applications require explosion resistant motors and careful consideration of all system components to insure the safe handling of such gas streams. The AMCA Standard (99-0401-86) Classification for Spark Resistant Construction deals with common explosion resistant fan construction requirements. The Standard contains guidelines that are to be used by both the manufacturer and user as a means of establishing general methods of construction. The exact method of construction and choice of alloys is the responsibility of the manufacturer; however, the customer must accept both the type and design with full recognition of the potential hazard and the degree of protection required.

Motor types

Fan and blower applications for use on AC power employ shaded-pole, permanent-split capacitor, split

phase, capacitor start, and three-phase motor types. Each type has electrical characteristics, which adapt it to specific load requirements or unit limits. Motor costs vary due to construction features and accessories. A squirrel cage induction motor is the most common motor. It is both rugged and simple in design, making it both economical and reliable.

Single-phase induction motors

Single-phase power does not naturally create a rotating magnetic field. Motors operating on single-phase power must include additional means to start the rotor moving. Once moving, the rotor induces a rotating magnetic field that sustains operation. Therefore, in some single-phase motors, the starting circuit is “opened” after the rotor reaches a predetermined speed. In other types, the start circuit remains engaged. How single-phase motors are started, and the effect this has on torque, is often the factor that determines which single-phase motor type best fits the application. The fan manufacturer normally chooses the correct motor type for the application. The following explains single-phase motor types.

Shaded pole: These motors have only one main winding and no start winding. Starting is accomplished through a design that uses a copper ring around a small portion of each motor pole. This “shades” that portion of the pole, causing the magnetic field in the ringed area to lag the field in the non-ringed portion. The reaction of the two fields initiates rotation.

Since it lacks a start winding, starting switch, or capacitor, the shaded pole motor is electrically very simple and inexpensive. Speed can be controlled by varying the voltage. These motors offer poor starting torque, typically 25 to 75 percent of rated load, and very low efficiency. These motors typically are up to ½ horsepower and have sleeve bearings.

*Application:
With low initial cost, low-torque, and small horsepower, applications such as small blowers, ceiling exhaust fans, and small*



Shaded pole motor

appliances. These motors are commonly used with speed controllers.

Permanent split capacitor (PSC): These motors do not have a starting switch or a capacitor strictly for starting. Instead, these motors have a run-type capacitor that is permanently connected in series with the start winding. This makes the start winding an auxiliary winding after the motor reaches running speed. Maintenance is low due to the lack of a starting switch. (A capacitor is a device that stores electrical energy. It is used to change the timing of the current flow in the start windings, which helps to establish a rotating magnetic field.)

The run capacitor must be designed for continuous use, it cannot provide the short-term boost of a starting capacitor. Therefore, starting torque of a PSC motor is low, ranging from 30 to 150 percent of rated load, which makes the motors unsuitable for hard-to-start loads.

These motors have several advantages: With no starting mechanism, they can be designed for easy reversing. They are considered to be the most reliable single-phase motor, primarily because a starting switch is not required. These motors typically are available up to 1 horsepower and have ball bearings.

Application: These motors have a wide variety of applications. Examples include direct drive fans, blowers with low starting torque requirements and intermittent cycling applications, and for use with speed controls.

Split phase: Also called induction-start/induction-run motor, is perhaps **the simplest kind of single-phase motor**. The stator has two types of coils; one is called the running winding and the other the starting winding.

The start winding is made with smaller gauge wire than the run winding and has much higher resistance. This results in different currents and magnetic fields in the two windings. These two magnetic fields, displaced from each other, form a rotating field that causes the rotor to turn.

The split phase motor's simple design is typically less expensive than other single-phase motor types. However, the simplicity limits performance. Starting torque is low; 100 to 175 percent of rated load. In addition, the split phase motor develops high starting current relative to motor horsepower, also

called locked rotor current, and has unreliable thermal protection due to the high locked rotor current relative to running current. Also these motors usually are designed for single voltage, limiting application flexibility. These motors typically are up to ¾ horsepower and have ball bearings.

Application: Good applications for split phase motors include small fans, blowers, and other low starting torque applications with low horsepower requirements.

Greenheck primarily uses split phase motors on direct drive units like small props and small centrifugal units.

Capacitor start / Induction run: This design results in a wide range of applications for industrial use. It is similar to a split phase motor, but has a much heavier start winding with a capacitor placed in the path of the electrical current to the starting winding to provide a starting boost. A capacitor motor can usually be recognized by the capacitor can or housing mounted on the stator.

These motors have several advantages over split phase motors. Since the capacitor is in series with the start circuit, it creates more starting torque. Typical starting torque ranges from 200 to 400 percent of rated load. Plus, the starting current is much lower than the split phase due to the larger wire in the start circuit. This allows higher cycle rates and reliable thermal protection.

This motor is more expensive than a split phase design because of the additional cost of the start capacity. But the application range is much wider because of higher starting torque and lower starting current relative to motor horsepower. These motors typically are used up to 2 horsepower, but are available in larger horsepowers. With anything larger than 2 horsepower, there maybe fit problems. These motor typically have ball bearings.

Application: Ideal for a wide range of belt driven applications like medium sized blowers, as well as many direct drive applications.

Greenheck uses them mainly on larger belt driven propeller fans and large centrifugal units.



Cap start motor

Three-phase induction motors (polyphase)

Three-phase power naturally creates a rotating magnetic field, no additional windings or switches are needed within the motor for starting. The simplicity of a three-phase induction motor can be attributed to the three-phase power supplied to the stator windings. Three-phase power can be thought of as three different single-phase power supplies. Three identical sets of running windings are mounted in the stator, and each set of windings is connected to a different phase of the power sources. The increase and decrease, or rise and fall of the current in each phase produces the rotating magnetic field. In turn, the rotation of the magnetic field produces the twisting motion in the motor shaft. These motors have the highest efficiencies and typically have ball bearings.

The polyphase or three-phase induction motor has been almost universally adopted in the industry as the most practical electric motor. These motors are available in a range from ½ hp to hundreds of horsepower. Their characteristics can be adapted to suit any type of load and to serve practically every industrial need. Below is a summary chart showing the major differences between each motor type.

Three-phase motors can not be used with speed

controls like single-phase motors, but three-phase inverter duty motors can be used with VFDs (Variable Frequency Drives). VFDs not only vary the voltage like a speed controller, but they change the frequency with the voltage. Inverter duty motors require heavier insulation on the internal wires, due to the extra heat generated when used with a VFD.

Applications: These motors are typically used on large fans and are recommended when the horsepower is greater than ½ hp and when additional motor features are required. These can be available for use with VFDs where the speed of the fan or pump needs to change.

Motor speed

The number of poles determines the speed of the motor. The number of poles is related to the number of coil centers. Sixty cycle (Hz) power cycles 60 times each second, or 3600 times each minute. When the stator is wound in the form of two poles, they change their polarity 3600 times each minute. The rotating magnetic field induces the rotor conductors to follow. All alternating current induction motors “slip”. They cannot keep up with the speed of the pole changes within the stator. The speed of the magnetic field within the stator is called the synchronous speed of the motor. A two-pole motor has a synchronous speed of 3600 rpm on 60 cycle

Motor Types Summary Chart						
Displays various motor types and their key differences						
Motor Type	Cost	Nominal Efficiency	Starting Torque	Speed Control	Reversible	Typical Applications
Shaded Pole	Lowest	Lowest	Lowest	Yes	No	<ul style="list-style-type: none"> • Designed for specific fans • Used on small direct drive fans only • Can be used with speed controllers
PSC	Low	Low	Low	Yes	Yes	<ul style="list-style-type: none"> • Constant torque • Used on small direct drive fans only • Can be used with speed controllers
Split Phase	Average	Good	Medium	No	Yes	<ul style="list-style-type: none"> • Separate start windings to control starting amps • Used on medium sized fans
Capacitor Start	Average	56% @ ¼ hp 74% @ 3 hp High	High	No	Yes	<ul style="list-style-type: none"> • Used for higher starting torque requirements • Used on medium and large fans • Most common
Three Phase	Average	68% @ ¼ hp 87% @ 10hp Highest	High	No	Yes	<ul style="list-style-type: none"> • Efficient electromechanical device • Used on large fans • Wide range of available motor options • Available for use with VFDs

(Hz) alternating current. However, slip accounts for an actual speed of 3450 rpm.

This simple formula will help determine the synchronous speed (no-load) of an electric motor.

$$\frac{\text{Frequency (Hertz)} \times 120}{\text{Number of Poles}} = \text{Synchronous rpm}$$

The chart below shows the actual speed, synchronous speed, and number of poles on an AC motor.

Actual Speed	Synchronous Speed	Number of Poles
3450	3600	2
1725	1800	4
1140	1200	6
850	900	8

Multi-speed motors

Special multi-speed motors are available in two or three speeds. Industrial applications usually only deal with the more common two-speed motors.

- Two-speed, single winding motor: These motors are called “consequent pole” motors. The low speed on a single winding motor is always one-half of the higher speed. If requirements dictate speeds of any other ratio, a two-winding motor must be used.
- Two-speed, two winding motor: A separate winding is installed in the motor for each desired speed (e.g., 1750/1160 rpm). Speeds with a 2:1 ratio (e.g., 1750/860 rpm) can be delivered by two-winding motors as well as by single-winding motors.

Since rpm and cfm are directly proportional, the cfm of a ½ reduction motor is roughly ½ less than high speed. The ½ reduction motor has a cfm of roughly ½ less than high speed.

The choice between one-winding and two-winding motors is affected by the desired speed, motor price, wiring complexity, and physical size. One-winding motors have lower prices than two-winding motors but usually require special higher priced starters and disconnect switches.

Many small direct drive fans like Greenheck's G, CUE, and SQ use shaded pole three speed motors.

The three speeds are 1050, 1300, and 1550 rpm. A commonly asked question is what color wires correspond to what speeds? Black is high speed, blue is medium speed, and red is low speed.

Voltage and phase

Voltage and phase are limited to the power supply available at the installation site. The general rule of thumb is to use polyphase (three-phase) motors of the highest available voltage in order to achieve the greatest efficiency. Single-phase motors of similar horsepower often cost more than polyphase because of the need for capacitors, centrifugal switches, etc.

In most industrial sites, the power supply typically used for the average polyphase motor is 230 or 460 volts at 60 Hertz. Single-phase motors are available for service on 115/230 volts for 3 hp and smaller. Motors up to 10 hp are available for 230 volt service in single-phase, but are not very common.

The key to determining what motor voltage and phase to select is understanding the motor manufacturer's original design. Most motors operate successfully within 10% of nameplate voltage with the exception of the tri-voltage 208-230/460 volt rating. (The 230/460 volt rating is not generally recommended for 208 volt service unless authorized by the motor manufacturer.) Motor service life can be shortened considerably if the motors are operated outside the + 10% variance range.

Service factor

The service factor is a measure of continuous overload capacity at which a motor can operate without damage, provided the other design parameters such as rated voltage, frequency, and ambient temperature are within norms. Example: A ¾ hp motor with a 1.15 service factor can operate at .86 hp (.75 hp x 1.15 = .862 hp) without overheating or otherwise damaging the motor if rated voltage and frequency are supplied at the motor's leads. Some motors have higher service factors than the NEMA standard.

General purpose open motors usually have a service factor greater than 1.0 and totally enclosed motors usually have a service factor not exceeding 1.0. When the motor nameplate voltage and frequency are maintained, the motor can be run up to the capacity as shown on the motor nameplate.

For easy reference, standard NEMA service factors for various horsepower motors and motor speeds are shown in this table.

Standard motors are rated under the assumption they will be operated at sea level in an ambient atmosphere of 40° C.

**Ambient:* Ambient temperature is defined as that temperature which the motor will have in the surrounding air as an expected maximum.

NEMA service factor at synchronous speed (rpm) (for dripproof motors)				
hp	3600	1800	1200	900
1/6, 1/4, 1/3	1.35	1.35	1.35	1.35
1/2	1.25	1.25	1.25	1.25
3/4	1.25	1.25	1.15	1.15
1	1.25	1.15	1.15	1.15
1-1/2 Up	1.15	1.15	1.15	1.15

It is assumed there is no difference in cooling between sea level and 3,300 feet. The air at higher altitudes is thinner and can't remove as much motor heat. As a result, the motor runs hotter. When running a motor above 3,300 feet, the following alternatives are available to keep a motor operating within the limits the insulation class allows. All options are dependent upon the actual temperature rise at sea level.

Do not run the motor into the service factor. For example, a motor rated at 1.15 service factor will operate successfully at 9,000 feet at a 1.0 service factor.

If a motor is operated at a lower ambient temperature, it may not need to be modified for altitude. For example, a 40° C ambient motor in a 20° C ambient condition could be operated at an altitude of up to 9,900 feet without a reduction in service factor.

Utilizing a higher efficiency motor will result in more flexibility due to lower losses and lower temperature rise at sea level.

Efficiency

Motors are converters of energy. Their job is to convert electrical energy into mechanical energy.

Efficiency ratings tell how well they do their job. By definition, efficiency is the ratio of output power (mechanical) to input power (electrical). Single-phase AC induction squirrel cage peak motor efficiencies range from as low as 30% to as high as 65%, depending on the motor type and design. Motor efficiencies also depend on the actual motor load versus rated load.

The best motor for the job is often designated by the nature of the load. Motor efficiency usually is

greatest at the full load rating and falls off rapidly for under and overloaded conditions. It is a misconception that a motor running well below its maximum load rating will run cooler and more efficiently. Over sizing AC motors reduces efficiency by a substantial amount, causing a larger part of the input energy to be dissipated as heat. On the other end of the scale, overloading of motors is a much better understood concept

because there are signs that indicate poor motor selection (reduced speed, high amperage draw, tripped motor overloads).

From an efficiency standpoint, it is typically best to run an AC single phase, squirrel cage motor at no less than 75% full load and no greater than 125% full load. Motor efficiency is greatest near its full load rating.

EPACT: The intent of the EPACT law is to raise the efficiency levels of motors by placing requirements on the manufacturer and importation of designated motors. With the passage of the Energy Act of 1992, the government mandated that after October, 1997 all general purpose motors must meet nominal full load efficiency levels. The nominal efficiency values that EPACT uses are published in NEMA Standard MG-1, table 12-10. These nominal efficiencies are for operation at full rated load and are the values found on motor nameplates.

At this time, EPACT only applies to general purpose motors. A general purpose motor in NEMA terms is a motor that is single speed, foot mounted, polyphase, squirrel cage induction, T-frame, design A or B, 230/460 volt, and 60 Hz. General purpose motors can be applied in many different applications. They may include modifications only

if the modifications don't change the electrical characteristics or mechanical construction of the motor. General Purpose motors can be installed in the airstream or out of the airstream.

Definite purpose motors do not have to comply with EPACT at this time. A definite purpose motor is a motor of the same electrical characteristics and mechanical construction as a general purpose motor except that a definite purpose motor can only be used in specific applications. A TEAO motor is a definite purpose motor because the motor has to be mounted in the airstream to keep it cool.

Special purpose motors are also exempt from EPACT requirements at this time. A special purpose motor has special electrical characteristics or mechanical construction such as thrust or sleeve bearings, brakes or winding encapsulation.

Energy efficient motors are covered by EPACT with the following attributes:

- ODP (Open dripproof), TEFC (Totally enclosed fan cooled), & EXP (Explosion resistant)
- Three-phase
- 230/460 volt
- 2, 4, and 6 pole (3450, 1725, and 1140 rpm)
- 143T frame and larger
- 1 hp to 200 hp
- General purpose

Insulation

Winding insulation temperature rating, and motor operating temperature should be considered together when specifying motors. Ideally, a motor should have a relatively high insulation temperature rating and a relatively low operating temperature. This provides a thermal margin in the event of motor overload, severe starting duty or severe

running conditions. (A well-accepted rule of thumb is for every 10° C that the motor temperature exceeds its rated insulation temperature, the insulation life is reduced by half.)

Insulating materials or combinations of such materials are grouped into "temperature tolerance classes", and these materials have been found to give satisfactory service and long life when operated within these temperature limits.

NEMA specifies letter designations for motor insulation temperature ratings. These insulation temperature ratings are noted as: Classes A, B, F, and H, and are rated at 105, 130, 155, and 180 degrees C, respectively.

NEMA also specifies allowable temperature rises for motors at full load (and at service factor if applicable). These allowable temperature rises are based upon a **reference ambient temperature of 40° C**, and are determined by the "resistance method", in which the resistance of the windings is measured. The temperature of the winding is a function of resistance of the winding.

NEMA allowable temperature rises (at full load) for a 1.0 service factor motor are 60, 80, 105, and 125 degrees C for classes A, B, F, and H insulation, respectively. NEMA allowable temperature rises (at service factor) for a 1.15 service factor motor are 70, 90, and 115° C for classes A, B, and F insulation, respectively.

Adding the NEMA allowable temperature rise of 105° C (for a Class F insulated, 1.0 service factor motor), to the reference ambient temperature of 40° C, results in a total operating temperature for the motor of $(105 + 40) = 145° C$. The 10° C temperature differential between the Class F insulation maximum temperature rating (155° C) and the

Classes	Motor Insulation Temperature Ratings	Allowable Temperature Rises (at full load)	
		1.0 service factor motor	1.15 service factor motor
A	105° C	60° C	70° C
B	130° C	80° C	90° C
F	155° C	105° C	115° C
H	180° C	125° C	not defined

allowable maximum temperature (145° C) provides an allowance for the “hot spot” temperature of the interior of the winding, which cannot be measured directly. The overall winding resistance is the sum of the resistance of the cooler end turns, and the warmer (hot spot) windings embedded in the stator slots.

Class B is the most common insulation class used on most 60 cycle US motors, Class F is the most common for international and 50 cycle motors.

In conclusion, in standard fan applications, insulation class is not very important. But with any unusual or high temperature applications, insulation class is an important factor.

Mounting (basic types)

A motor can be mounted to the device its driving (fan) by several different ways. The fan manufacturer normally has the mounting type built into the construction of the fan.

Solid, rigid, or footed: is solidly fastened to equipment through a metal base which is bolted, cast, or welded to the motor shell or frame.



Rigid mount motor

Resilient, cushion or rubber mount: Motor shell is isolated from the base by vibration-absorbing rubber rings on the end shields, to reduce vibration to the equipment.



Resilient mount motor

Extended thru bolts: The motor has bolts extending from the front or rear, by which it is mounted. Used on small, direct drive fans and blowers.



Thru bolt mounted motor

Motor protection (Thermal overload)

A thermal protector, automatic or manual is mounted in the end frame or on a winding and is designed to prevent a motor from getting too hot, causing possible fire or damage to the motor. Protectors are generally current and temperature sensitive. Some motors have no inherent protector, but they should have protection provided in the overall system’s design for safety.

Basic types of overload protectors include:

- Automatic reset: After the motor cools, this line-interrupting protector automatically restores power. It should not be used where unexpected restarting would be hazardous.
- Manual reset: This line-interrupting protector has an external button that must be pushed to restore power to the motor. Use where unexpected restarting would be hazardous, as on saws, conveyors, compressors and other machinery.
- Resistance temperature detectors: Precision-calibrated resistors are mounted in the motor and are used in conjunction with an instrument supplied by the customer to detect high temperatures.

Underwriters Laboratory (UL) Listing

Motors are designed to meet safety specifications as set by an organization called Underwriters Laboratories, Inc. UL is an independent testing organization specializing in testing products, systems and materials with particular reference to life, fire and casualty hazards. Standards have been developed for motors and controls in cooperation with the manufacturers.

In order for fans to qualify for UL Listings, the manufacturer must furnish to UL a complete outline of all the motors to be used with that product. This outline of motors is specific to each fan model and fan manufacturer.

Motors must be UL Listed by the motor manufacturer, by manufacturer's model number, speed, horsepower and enclosure type. UL Marks can only be applied to a specific fan model using a motor approved by UL.

What does this mean? It means that customers must accept specific motors when UL Listings are required. It may also limit a customer specifying

motors of a given brand or motors with special features.

Most motors and electrical components are UL recognized. The fan manufacturer works with UL to get the UL recognized motor tested with the fan to get the fan and motor combination UL Listed.

Greenheck's motor testing lab puts their suppliers' motors through extensive testing, which exceeds the requirements of UL standards. Tests include: starting current, input current, over/under voltage, high temp (over heating), speed control (when used), start/stop (cycle), motor noise, and reliability (shafts and bearings). Greenheck attempts to duplicate the field's worst case scenario in its testing, which assures a safe, long lasting product. These tests assure that the motor's temperature is well below the manufacturers' recommended operating temperature of the insulation. Additionally, final product testing prior to shipment assures a dependable product at startup.

Testing at Greenheck

In today's environment, customers are demanding more from the products they place in their buildings. Testing is an important part in delivering a quality product. Our stringent testing procedures during the product development cycle allow us to meet changing market needs while making Greenheck products even more reliable. We have one of the most comprehensive testing facilities in the market including three AMCA registered air chambers.

Summary

The information in this article is a guideline to help communicate a better overall understanding of motors and assorted motor specifications. Don't let your job get delayed by unnecessary special design requests caused by incorrect job specifications. The specifier should avoid writing one general motor spec to cover the range from general purpose to heavy duty industrial purpose motors. This could force a general clean air motor application, where a commonly used motor is required, to a specification where a special motor is required. The end result is a general clean air application costing more time and money. The bottom line is make sure the motor specification is correct for the application.

Greenheck's Computer Aided Product Selection program (CAPS) recommends the motors required for 96% of all applications.

To assist you with motor application questions, Greenheck's engineers have close to 50 years of experience in motor selection and work closely with our vendors to ensure customers receive the highest quality products.

Glossary

Ambient temperature – Temperature of the motor's surroundings. Usually 40° C (104° F).

AMCA Standard (99-0401-86) on spark resistant construction:

- Type A: All parts of the fan in contact with the air or gas being handled shall be made of nonferrous material (material less than 5% iron or any other material with demonstrated ability to be spark resistant). Steps must be taken to assure that the impeller, bearings, and shaft are adequately attached and/or restrained to prevent a lateral or axial shift in these components.
- Type B: The fan shall have a nonferrous impeller and nonferrous ring around the opening through which the shaft passes. Ferrous hubs, shafts, and hardware are allowed provided construction is such that a shift of impeller or shaft will not permit two ferrous parts of the fan to rub or strike.
- Type C: The fan shall be so constructed that a shift of the impeller or shaft will not permit two ferrous parts of the fan to rub or strike.

Bearing life - Rating life, L10 (B10), is the life in hours or revolutions in which 90% of the bearings selected will obtain or exceed. Median life (average life), L50 (B50), is the life in hours or revolutions in which 50% of the bearings selected will obtain or exceed. Many of Greenheck's spun aluminum products have a L10 rating of 100,000 hours.

Breakdown torque – The maximum torque a motor will develop at rated voltage without a relatively abrupt drop or loss in speed.

Capacitor – A device that, when connected in an alternating current circuit, causes the current to lead the voltage in time phase. The peak of the current wave is reached ahead of the peak of the voltage wave. This is the result of the successive storage and discharge of electric energy used in single-phase motors to start, or in three-phase motors for power factor correction.

Capacitor start – The capacitor start single-phase motor is basically the same as the split phase start, except that it has a capacitor in series with the starting winding. The addition of the capacitor results in greater starting torque with much less

power input. As in the case of the split phase motor this type can be reversed at rest, but not while running unless special starting and reversing switches are used. When properly equipped for reversing while running, the motor is much more suitable for this service than the split phase start since it provides greater reversing ability at less watts input.

Conduit box – Metal container usually on the side of the motor where the stator (winding) leads are attached to the power supply leads.

Constant hp (horsepower) – A designation for variable speed motors used for loads requiring the same amount of horsepower regardless of their motor speed during a normal operation.

Constant torque – Refers to loads with horsepower requirements that change linearly at different speeds. Horsepower varies with the speed, i.e., 2/1 hp at 1800/900 rpm (seen on some two-speed motors). Applications include conveyors, some crushers and constant-displacement pumps.

CSA – Canadian Standards Association like UL, sets specific standards for products used in Canada.

Current – The flow of an electrical charge through a conductor with the ability to overcome resistance and perform work. This time rate of flow of electrical charge is measured in amps (ampere).

Cycles per second (hertz) – One complete reverse of flow of alternating current per rate of time. (A measure of frequency.) 60 Hz (cycles per second) AC power is common throughout the US and 50 Hz is common in many foreign countries.

Dual torque - A dual speed motor with torque values that vary with speed (as the speed changes the horsepower remains constant).

Dual voltage - Some motors can operate on two different voltages, depending upon how the motor is built and connected.

Duty - Duty rating is determined by the enclosure, amount of cooling, and type of insulation used in the motor. This rating is the length of time that the motor may be operated without overheating or decreasing the normal life span of the motor. (Greenheck's motors are continuous duty).

Efficiency - The ratio or comparison of useful power output to the power input, expressed in the same units. Motors are converters of energy. Their job is to convert electrical energy into mechanical energy. Efficiency ratings indicate how well they do that job. By definition, efficiency is the ratio of output power (mechanical) to input power (electrical). A number of terms are used to describe motor efficiency. These include “nominal”, “minimum guaranteed”, and “quoted” efficiencies. “Nominal” efficiency is the average efficiency of a large number of motors of a given rating, within the limits of the NEMA allowable 20% tolerance. “Minimum guaranteed” efficiency is, as the description implies, the minimum efficiency value that any motor of a given rating would ever produce under test. “Quoted” efficiency is the average efficiency value of a large number of motors of a given rating, when tested to the tolerances of the CSA-C390 efficiency test method.

Electric motor – A device which transforms electrical energy into rotational mechanical energy.

Electrical unbalance - In a three-phase supply, where the voltages of the three different phases are not exactly the same; measured as a percent of unbalance.

Energy – The ability to do work. Energy cannot be created or destroyed, but it may be transferred among various bodies or changed from one form to another.

Explosion resistant motors – Motors designed to safely operate in hazardous locations. There are various degrees of hazardous locations and the appropriate motor must be picked for each classification.

Frame – The supporting structure for the stator parts. In a direct-current motor, the frame usually forms a part of the magnetic circuit. It includes the poles only when they form an integral part of it. Motor frames may be of cast iron, or rolled steel or rolled aluminum. Cast iron is generally considered to be the most suitable frame material for industrial use, due to its high resistance to corrosion, extreme rigidity, etc.

Frame size – Refers to a set of physical dimensions of motors as established by NEMA. These dimensions include critical mounting dimensions.

NEMA 48 and 56 frame motors are considered fractional horsepower sizes even though they can exceed one horsepower. NEMA 143T to 449T is considered integral horsepower AC motors and 5000 series and above are called large motors.

Frequency/Hertz (Hz) – Rated input frequency in cycles per second of motor’s power supply.

Full-load current - The current flowing through the line when the motor is operating at full-load torque and full-load speed with rated frequency and voltage applied to the motor terminals.

Full-load torque - The torque of a motor necessary to produce its rated horsepower at full-load speed, sometimes referred to as running torque.

Horsepower – As applied to an electric motor, the horsepower is an index of the amount of work the motor can produce in a period of time. For example: One horsepower equals 33,000 foot pounds of work per minute. A one horsepower motor, with suitable gearing and neglecting all losses, can lift 33,000 pounds one foot in a minute, or one pound 33,000 feet in a minute. Assuming 100% efficiency, 746 watts of electrical power will produce one horsepower.

Insulation class – Insulation class defines the maximum safe operating temperature of a motor; such ratings are A, B, F, and H. This maximum temperature is the sum of the maximum ambient and maximum rise temperatures.

Insulation life – Insulation life is defined as the time it takes for a material’s tensile strength to be cut in half, when operated at its full rated temperature. This is typically 20,000 hours.

Insulator – A material or combination of materials which effectively resists the passage of an electric current.

Inverter - An electronic device that converts fixed frequency and fixed voltages to variable frequency and voltage. Enables the user to electrically adjust the speed of an AC motor.

Inverter duty - Heavy duty motor with better thermal overload and insulation to protect against high voltage spikes. Designed to be used with a variable frequency drive (VFD) or inverter.

Locked rotor torque - The minimum torque that a motor will develop at rest for all angular positions of the rotor (with rated voltage applied at rated frequency).

Laminations - Metal sheets (usually of a silicon-alloy steel) stacked together and riveted or otherwise fastened to form the core of an electromagnet. The windings are placed in or around this core.

Motor protection - Devices that protect a motor from overloads, overheating or short circuits.

Motor types -

- **Shaded Pole** - Lowest starting torque, low cost, low efficiency, no capacitors. No start switch, used on small direct-drive fans and small gear motors.
- **PSC (Permanent Split Capacitor)** - Similar to shaded pole applications except much higher efficiency, lower current and higher horsepower capacity. Has run capacitor in circuit at all times.
- **Split Phase** - Moderate to low starting torque, no capacitor and has starting switch. Used on easy start, belt drive fans and blowers, light start pump applications and gear motors.
- **Capacitor Start** - Designed in both moderate and high starting torque types with both having moderate starting current and high breakdown torque. Uses include large fans, conveyors, and air compressors.

Three-Phase - Generally, three-phase induction motors have a high starting torque, high power factor, high efficiency, and low current. Does not use a switch, capacitor, or relay. Suitable for use on larger commercial and industrial applications.

Multi-speed motor - One which can be operated at any one of two or more definite speeds, each being practically independent of the load. For example, a direct current motor with two armature windings, or an induction motor with windings capable of various pole groupings.

NEMA - National Electrical Manufacturers Association (NEMA) is a nonprofit U.S. organization consisting of members from the manufacturing sector. One of the stated purposes of NEMA is "to promote the standardization of electrical apparatus and supplies".

Overload protection - Relays that protect motors against overheating due to loads above their rated capacity.

Rating - The designated limit of operating characteristics of a motor, apparatus or device based on definite conditions. Load, voltage, frequency, and other operating characteristics may be given in the rating.

Resilient mounting - A suspension system or cushioned mounting designed to reduce the transmission of normal motor noise and vibration to the mounting surface. This type of mounting is typically used in fractional horsepower motors for fans and blowers.

Rotor - The rotating part of most alternating current motors.

Service factor - The service factor is a measure of the overload capability of a motor. Essentially, it is a factor by which the motor horsepower may be multiplied, to obtain the rating at which the motor can be operated continuously, when supplied by rated voltage and frequency. A service factor of 1.15 is common for most NEMA frame ratings these days. A 1.15 service factor, 100 hp motor could deliver 115 hp continuously, without exceeding its design temperature rise, with rated voltage and frequency applied.

Slip - The difference between the speed of the rotating magnetic field (which is always synchronous) and the rotor in a non-synchronous induction motor is known as slip. It is expressed as a percentage of synchronous speed. Slip generally increases with an increase in torque.

Stator - That portion of an electrical motor which contains the stationary parts of the magnetic circuit with their associated windings.

Synchronous speed - The average speed of normal operation is exactly proportional to the frequency of the system to which it is connected.

Temperature Rise - The amount that a motor increases in temperature above ambient.

Thermal Overload - Consists of a heater element where motor current flows directly through. The heater element is in close proximity to a bi-metallic strip that bends and causes a contact to open when the current limit of the element is exceeded.

Torque – A force that produces or tends to produce rotation. Common units of measurement of torque are pound-feet, pound-inches, ounce-feet, and ounce-inches.

UL - Underwriter's Laboratories, an independent organization that sets safety standards for motors and other electrical equipment.

Volt – A unit of electrical potential or pressure.

Watt – A unit of electrical power, directly converted to work, the product of voltage and amperage. 746 watts are equal to one horsepower.

Winding insulation rating – Temperature rating of motor insulation.

