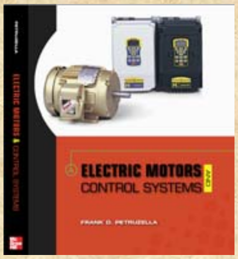
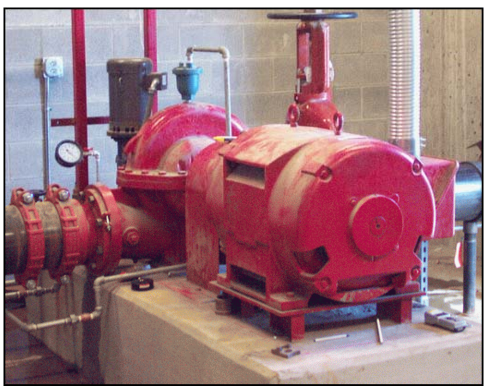


Chapter 5

Electric Motors

PART 6 Motor Selection

Electric motors come in many shapes and sizes. Some are standardized electric motors for general-purpose applications. Other electric motors are intended for specific tasks.



Electric Motor Driven Fire Pump

- **Applications include sprinkler system and water mist system.**

Electric motors should be selected to satisfy the requirements of the machines on which they are applied without *exceeding rated electric motor temperature.*

General Purpose Motor

Conveyor Motor

MECHANICAL POWER RATING

The *mechanical power rating* of motors is expressed in either horsepower (HP) or watts (W): 1 HP = 746 W.

Two important factors that determine mechanical power output are torque and speed.

$$\text{Horsepower} = \frac{\text{Torque} \times \text{Speed}}{\text{Constant}}$$

where

Torque is expressed in lb/ft.
Speed is expressed in rpm.

The value of the constant changes depending on the unit that is used for torque. For this combination the constant is 5252.

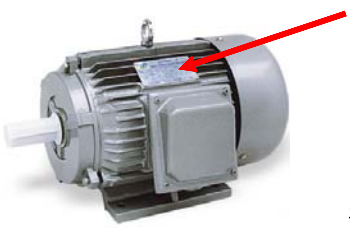
The slower the motor operates, the more torque it must produce to deliver the same amount of horsepower.

HP	F.L. rpm	F.L. Amps 460 V	N.L. Amps 460 V	F.L. Torque (lb-ft)
2	1750	3.0	1.7	6.0
2	1160	3.3	2.1	9.0

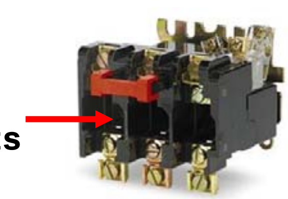
To withstand the greater torque, slow motors need stronger components than those of higher speed motors of the same power rating. For this reason, slower motors are generally larger, heavier, and more expensive than faster motors of equivalent horsepower rating.

CURRENT

Full Load Amps **is the amount of amperes the motor can be expected to draw under full load (torque) conditions and is also known as the *nameplate amps*.**



Nameplate full-load current rating of the motor is used when determining the size of overload sensing elements for the motor circuit.



Locked Rotor Current **is the amount of current the motor can be expected to draw under starting conditions when full voltage is applied and is also known as the *starting inrush current***

Service Factor Amps **is the amount of current the motor will draw when it is subjected to a percentage of overload equal to the service factor on the nameplate of the motor.**

For example, a motor with a service factor of 1.15 means it will handle 115% of normal running current indefinitely without damage.

CODE LETTER

NEMA code letters **are assigned to motors for calculating the locked rotor (LR) current in amperes based upon the kilovolt-amperes per horsepower per nameplate horsepower.**

The letters range in alphabetical order from A to V in increasing value of locked rotor current.

Locked-Rotor Code, kVA/hp			
A	0–3.15	G	5.6–6.3
B	3.15–3.55	H	6.3–7.1
C	3.55–4.0	J	7.1–8.0
D	4.0–4.5	K	8.0–9.0
E	4.5–5.0	L	9.0–10.0
F	5.0–5.6	M	10.0–11.2

LR current (single-phase motors)

$$= \frac{\text{Code letter value} \times \text{hp} \times 1{,}000}{\text{Rated voltage}}$$

LR current (three-phase motors)

$$= \frac{\text{Code letter value} \times \text{hp} \times 577}{\text{Rated voltage}}$$

Overcurrent protection **devices most be set above the locked-rotor current of the motor to prevent the overcurrent protection device from opening when the rotor of the motor is starting.**

Problem:

Determine the maximum locked-rotor current for a Code C, 460-volt,3-phase, 100-HP motor.

Locked-Rotor Code, kVA/hp			
A	0-3.15	G	5.6-6.3
B	3.15-3.55	H	6.3-7.1
C	3.55-4.0	J	7.1-8.0
D	4.0-4.5	K	8.0-9.0
E	4.5-5.0	L	9.0-10.0
F	5.0-5.6	M	10.0-11.2

Solution

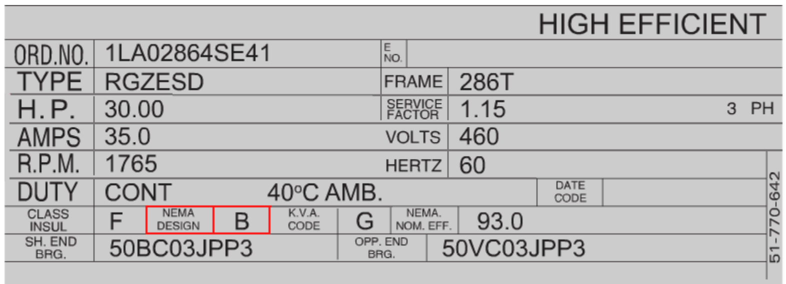
$$\text{LR Current} = \frac{\text{Code Letter Value x HP x 577}}{\text{Rated Voltage}}$$

$$= \frac{4\,x\,100\,x\,577}{460}$$

$$= 502\ Amps$$

DESIGN LETTER

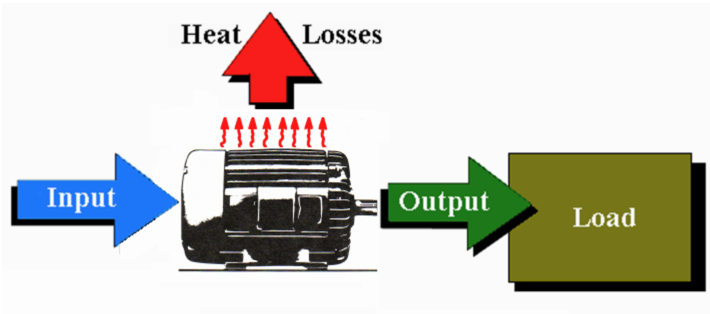
NEMA has defined four standard **motor designs** for AC motors using the letters **A, B, C, and D** to meet specific requirements posed by different application loads.



The *design letter* denotes the motor's performance characteristics relating to torque, starting current, and slip. Design B is the most common design.

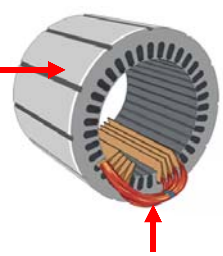
EFFICIENCY

Motor *efficiency* is the ratio of mechanical power output to the electrical power input, usually expressed as a percentage.

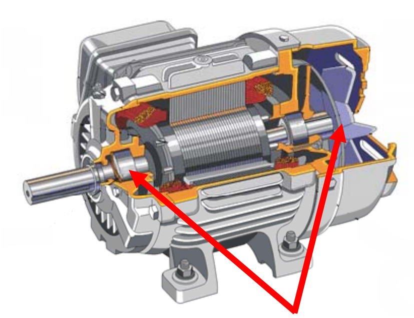


The power input to the motor is either transferred to the shaft as power output or is lost as heat through the body of the motor.

Core loss represents the energy required to magnetize the core material (**hysteresis**) and losses owing to the creation of small electric currents that flow in the core (**eddy currents**).

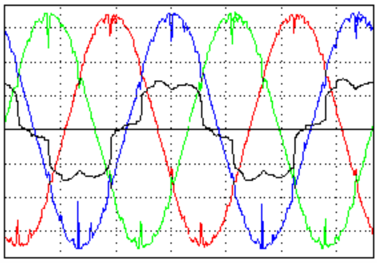


Stator and rotor resistance losses represent the I^2R heating loss due to current flow (I) through the resistance (R) of the stator and rotor windings and are also known as ***cooper losses***.



Mechanical losses include **friction** in the motor bearings and the fan for air-cooling.

Stray losses **are the losses that remain after primary copper and secondary losses, iron losses and mechanical losses.**

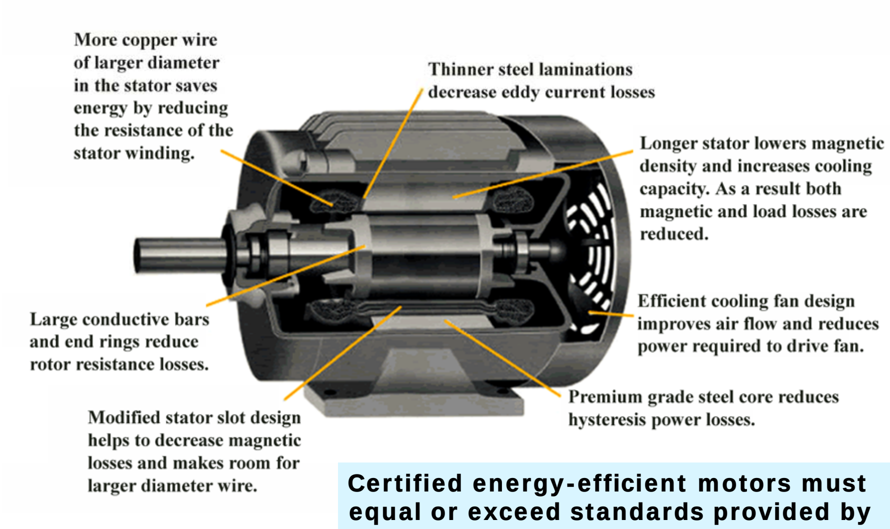


3-Phase Harmonic Power Distortion

The largest contribution to the stray losses is *harmonic energies* generated when the motor operates under load. These energies are dissipated as currents in the copper windings, harmonic flux components in the iron parts, leakage in the laminate core.

ENERGY-EFFICIENT MOTORS

Energy-efficient motors use less energy because they are manufactured with higher quality materials and techniques.

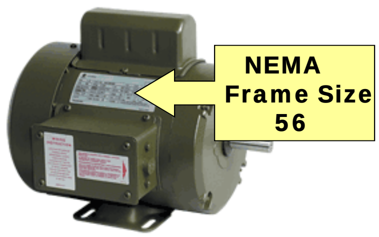


Certified energy-efficient motors must equal or exceed standards provided by NEMA in their publication MG-1.

FRAME SIZE

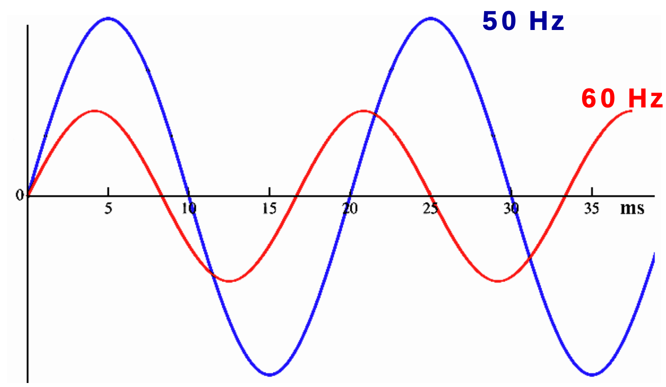
Motors come in various *frame sizes* to match the requirements of the application. In general, the frame size gets larger with increasing horsepower or with decreasing speeds.

NEMA prescribes standard frame sizes for certain dimensions of standard motors. As an example, a motor with a frame size of 56 will always have a shaft height above the base of 3-1/2 inches.



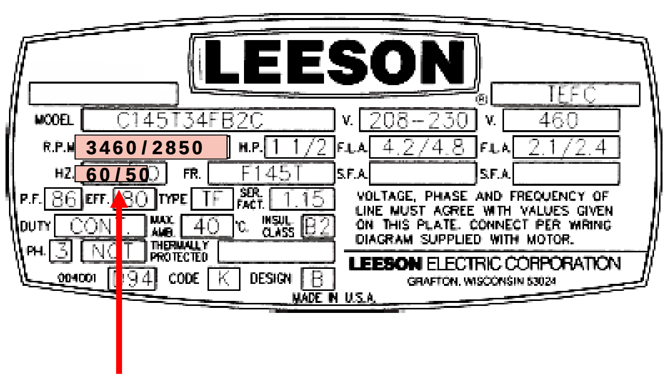
FREQUENCY

Frequency **refers to the line frequency of the power supply for which an AC motor is designed to operate at.**



Electric motors in the US and North America are designed to operate on 60-hertz power where most of the rest of the world uses 50 hertz.

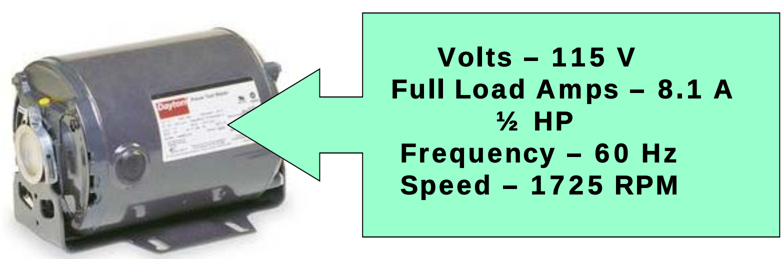
It is important that equipment designed to operate on 50 hertz is properly designed or converted to provide good service life at 60 hertz.



A change in frequency from 50 Hz to 60 Hz will result in a increase in rotor RPM.

FULL LOAD SPEED

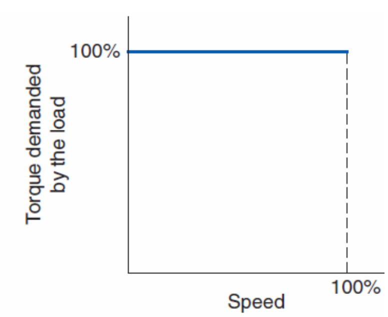
Full load speed **represents the approximate speed at which the motor will run when it is supplying full rated torque or horsepower.**

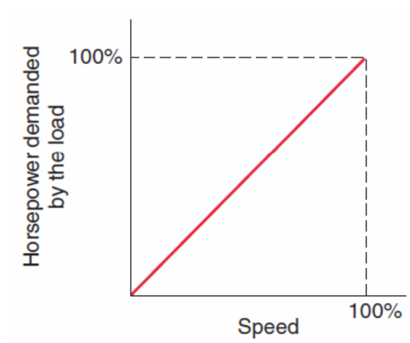


As an example, a typical four-pole motor running on 60 Hz might have a nameplate rating of 1725 RPM at full load, while its synchronous speed is 1800 RPM.

LOAD REQUIREMENTS

CONSTANT TORQUE LOADS - The torque required by the load is constant throughout the speed range. With this type of load as speed increases, the torque required remains constant while the horsepower increases or decreases in proportion to the speed.

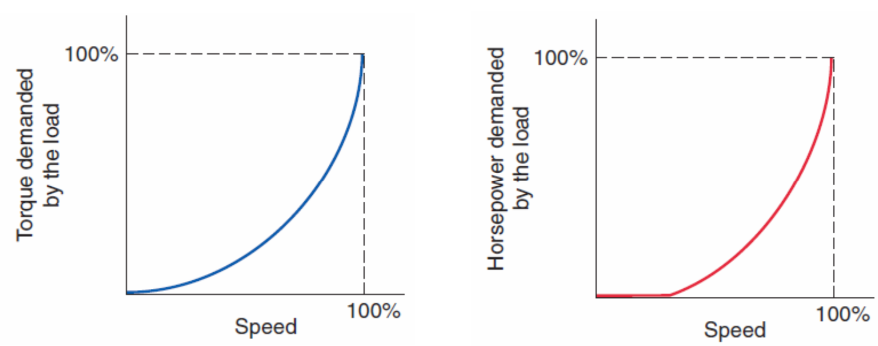




➢Typical constant torque load applications are conveyors, hoists, and traction devices.

➢A conveyor load requires about the same torque at 5 feet-per-minute as it does at 50 feet-per-minute. However, the horsepower requirement increases with speed.

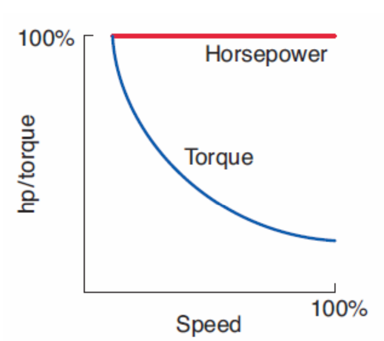
VARIABLE TORQUE LOADS- Variable torque is found in loads having characteristics, which require low torque at low speed, and increasing values of torque as the speed is increased.



➢Examples of loads that exhibit variable torque characteristics are centrifugal fans, pumps and blowers.

➢**When sizing motors for variable torque loads it is important to provide adequate torque and horsepower at the maximum speed.**

CONSTANT HORSEPOWER LOADS -Constant horsepower loads require high torque at low speeds and low torque at high speeds, which results in constant horsepower at any speed.



- One example of this type of load would be a lathe.

- At low speeds, the machinist takes heavy cuts, using high levels of torque. At high speeds, the operator makes finishing passes that require much less torque.

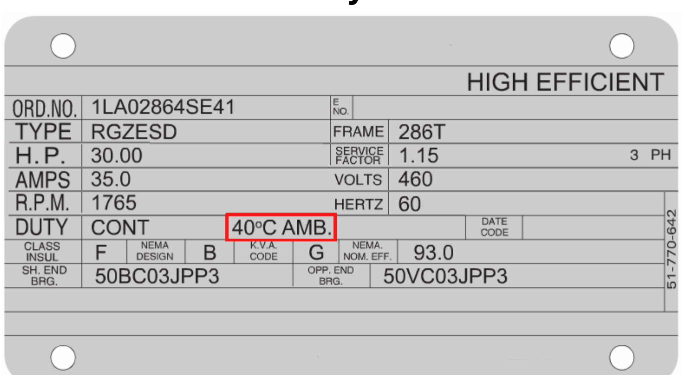
MOTOR TEMPERATURE RATINGS

A motor's insulation system separates electrical components from each other, preventing short circuits and thus, winding burnout and failure.

Checking motor temperature.

Insulation's major enemy is heat, so it's important to be familiar with the different motor temperature ratings in order to keep the motor operating within safe temperature limits.

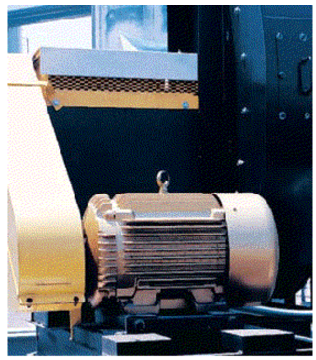
Ambient temperature is the maximum safe room temperature surrounding the motor if it going to be operated continuously at full load.



When a motor is started, its temperature will begin to rise above that the surrounding, or ambient air. In most cases the standardized ambient temperature rating is 40° C (104° F).

Temperature rise is the amount of temperature change that can be expected within the winding of the motor from non-operating (cool condition) to its temperature at full load continuous operating condition.

For example: if a motor is located in a temperature of 78° F, and then is started and operated continuously at full load, the winding temperature would rise from 78° F to a higher temperature. **The difference between its starting temperature and the final elevated temperature, is the motor's temperature rise.**



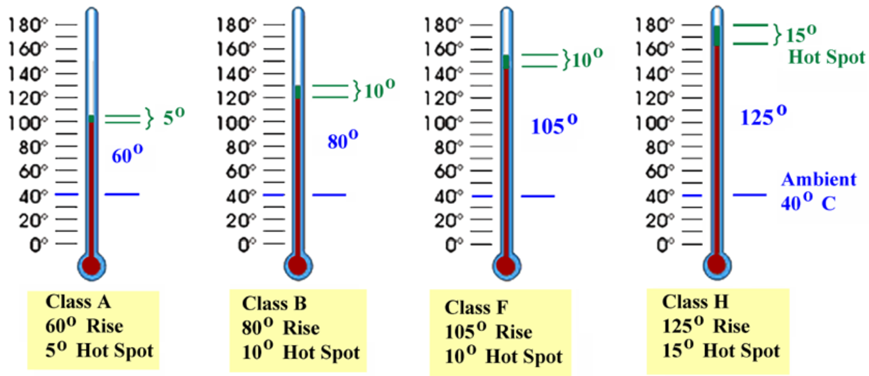
A **hot-spot allowance** must be made for the difference between the measured temperature of the winding and the actual temperature of the hottest spot within the winding, usually 5° C to 15° C depending upon the type of motor construction.

ORD.NO.	1LA02864SE41			E NO.			
TYPE	RGZESD			FRAME	286T		
H.P.	30.00			SERVICE FACTOR	1.15		3 PH
AMPS	35.0			VOLTS	460		
R.P.M.	1765			HERTZ	60		
DUTY	CONT	40°C AMB.				DATE CODE	
CLASS INSUL	F	NEMA DESIGN	B	K.V.A. CODE	G	NEMA. NOM. EFF.	93.0
SH. END BRG.	50BC03JPP3			OPP. END BRG.	50VC03JPP3		

51-770-642

The sum of the **temperature rise + the hot-spot allowance + the temperature of the ambient** must not exceed the temperature rating of the insulation.

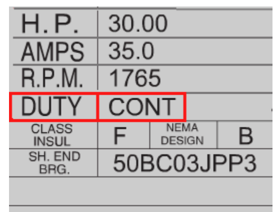
Insulations class of a motor is designated by letter according to temperature each is capable of withstanding without serious deterioration of its insulating properties.



DUTY CYCLE

The *duty cycle* refers to the length of time a motor is expected to operate under full load. Motor ratings according to duty are: continuous duty and intermittent duty.

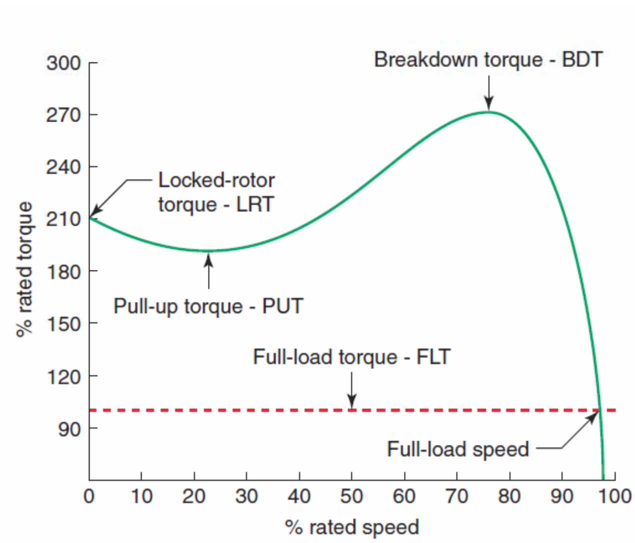
CONTINUOUS DUTY rated motors are rated to be run continuously without any damage or reduction in life of the motor. General purpose motors will normally be rated for continuous duty.



INTERMITTEN DUTY motors are rated for short operating periods and then must be allowed to stop and cool before restarting. Crane motors and hoists are often rated for intermittent duty.

TORQUE

Motor torque **is the twisting force exerted by the shaft of a motor.**



- **Locked rotor torque** is produced by a motor when it is initially energized at full voltage.

- **Pull-up torque** is the minimum torque generated by a motor as it accelerates from standstill to operating speed.

- **Breakdown torque** is the maximum amount of torque a motor can attain without stalling.

- **Full load torque** is produced by a motor functioning at a rated speed and horsepower.

MOTOR ENCLOSURES

Motor enclosures **are designed to provide adequate protection, depending on the environment in which the motor has to operate.**

The two general classifications of motor enclosures are *open* and *totally enclosed*

An **open** motor has ventilating openings, which permit passage of external air over and around the motor windings.

A **totally enclosed** motor is constructed to prevent the free exchange of air between the inside and outside of the frame, but not sufficiently enclosed to be termed airtight.

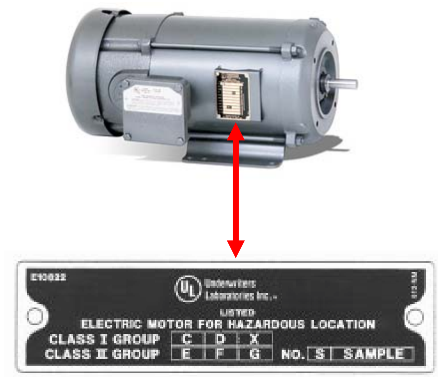
The open and totally enclosed categories are further broken down by enclosure design, type of insulation, and/or cooling method.

- **Open drip proof** motors are open motors in which all ventilating openings are so constructed that drops of liquid or solid particles falling on the motor at any angle from 0 to 15 degrees from vertical cannot enter the machine.

- **Totally Enclosed, Fan-Cooled** motors are enclosed motors equipped for external cooling by means of a fan integral with the motor, but external to the enclosed parts.

- **Totally Enclosed, Non-Ventilated** motors are enclosed motors generally limited to small sizes (usually under 5 HP) where the motor surface area is large enough to radiate and convey the heat to the outside air without an external fan or airflow.

➢**Hazardous Location** motors are designed with enclosures suitable for environments in which explosive or ignitable vapors or dusts are present, or are likely to become present. These special motors are required to ensure that any internal fault in the motor will not ignite the vapor or dust.



Every motor approved for hazardous locations carries a UL nameplate that indicates the motor is approved for that duty. This label identifies the motor as having been designed for operation in **Class I or Class II locations**.

METRIC MOTORS

When you need a replacement for a metric (IEC) the most practical way to proceed is to get an exact metric replacement motor.

When direct replacements are not available the following may need to be considered:

- **Metric motors are rated in kilowatts (KW) rather than horsepower (HP). To convert from kilowatts to horsepower multiply the KW rating of the motor by 1.34.**

- **NEMA and IEC standards both use letter codes to indicate specific mechanical dimensions, plus number codes for general frame size. IEC motor frame sizes are given in metric dimensions making it impossible to get complete interchangeability with NEMA frame sizes.**

- **Metric motors may be rated for 50 rather than 60 cycle speed.**

Speed, rpm

	Frequency 50 Hz		Frequency 60 Hz	
Poles	Synchronous	Full load (Typical)	Synchronous	Full load (Typical)
2	3,000	2,850	3,600	3,450
4	1,500	1,425	1,800	1,725
6	1,000	950	1,200	1,150
8	750	700	900	850

- **Although there is some correlation between NEMA and IEC motor enclosures, it is not always possible to show a direct cross-reference from one standard to the other.**
- **IEC winding insulation classes parallel those of NEMA and in all but very rare cases use the same letter designations**

➢NEMA and IEC duty cycle rating are different. Where NEMA commonly designates continuous or intermittent duty, IEC uses eight duty cycle designations.

IEC designations are:

S1 - Continuous duty.
S2 - Short-time-duty.,
S3 - Intermittent periodic duty.
S4 - Intermittent periodic duty with starting.
S5 - Intermittent periodic duty with electric braking.
S6 - Continuous operation with intermittent load.
S7 - Continuous operation with electric braking.
S8 - Continuous operation with periodic changes in load and speed.

➢CE is an acronym for the French phrase *Conformite Europeene* and is similar to the UL or CSA marks of North America. However, unlike UL (Underwriter's Laboratories) or CSA (Canadian Standards Associations), which require independent laboratory testing, the motor manufacturer through self certifying can apply the CE mark that its products are designed to the appropriate standards.