

# Variable Speed Operation

Guidelines for Application of General Purpose, Three Phase, Single Speed Motors on Variable Frequency Drives Meets NEMA MG1-2006 Part 30 and Part 31 Section 4.4.2 Unless stated otherwise, motor nameplates do NOT include listed speed range.

ENCLOSURE	EFFICIENCY	VARIABLE TORQUE	CONSTANT TORQUE								
		ALL FRAMES	56	143-215		254-286		324-365		404-449	
NEMA Motors		ALL POLES	ALL POLES	2-Pole	4&6 Pole	2-Pole	4&6 Pole	2-Pole	4&6 Pole	2-Pole	4&6 Pole
ODP	Standard (EPAAct exempt)	10:1	2:1	2:1	2:1	Contact Engineering					
	EPAAct compliant	10:1	N/A	2:1	2:1	2:1	2:1	Contact Engineering			
	NEMA Premium	10:1	N/A	10:1	10:1	10:1	10:1	10:1	10:1	2:1	2:1
TEFC	Standard (EPAAct exempt)	10:1	2:1	2:1	2:1	Contact Engineering					
	EPAAct compliant	10:1	N/A	2:1	10:1	2:1	10:1	2:1	2:1	2:1	2:1
	NEMA Premium	10:1	N/A	2:1	20:1	2:1	20:1	2:1	20:1 (1)	2:1	20:1 (1)
TENV	EPAAct compliant	10:1	N/A	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1
	NEMA Premium	10:1	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1	1000:1
Washdown TEFC	Standard (EPAAct exempt)	10:1	10:1 (2)	10:1 (2)	10:1 (2)	N/A	N/A	N/A	N/A	N/A	N/A
	EPAAct compliant	10:1	10:1 (2)	10:1 (2)	10:1 (2)	N/A	N/A	N/A	N/A	N/A	N/A
	NEMA Premium	10:1	10:1 (2)	10:1 (2)	10:1 (2)	N/A	N/A	N/A	N/A	N/A	N/A
Washdown TENV	Standard (EPAAct exempt)	10:1	1000:1	1000:1	1000:1	N/A	N/A	N/A	N/A	N/A	N/A
	EPAAct compliant	10:1	1000:1	1000:1	1000:1	N/A	N/A	N/A	N/A	N/A	N/A
	NEMA Premium	10:1	1000:1	1000:1	1000:1	N/A	N/A	N/A	N/A	N/A	N/A
Explosion Proof	All efficiency levels	Explosion Proof motors must be properly nameplated with inverter duty information prior to use on VFD. See Marathon catalog pages for specific rating capabilities. Motors with automatic overload protectors cannot be used on VFDs.									
IEC Motors		ALL FRAMES	63-90		100-225		250-315				
All Enclosures	All efficiency levels	10:1	20:1		Up to 20:1		Up to 2:1				

- Notes: (1) 324-449T, 4 & 6 Pole XRI motors are rated for 20:1 C.T. with fan modification; otherwise rated for 2:1 C.T. continuous duty, or 20:1 C.T. 60 minute duty at lowest RPM.  
 (2) Washdown TEFC motors are rated for 10:1 C.T. 60 minute duty or 2:1 C.T. continuous duty at lowest RPM.  
 Model numbers beginning with 5K are not suitable for use with Variable Frequency Drives.

## Application Notes

Bearing currents	Marathon Motors recommends that any motors used with Variable Frequency Drives be equipped with suitable means to protect the motor bearings from shaft currents caused by common mode voltages inherent with operation on a non-sinusoidal power supply. Marathon Motors offers several options for motors in non-classified (non-hazardous) locations, including ground brushes, insulated bearings and non-contact shaft grounding rings. For more information on ground brushes and bearing currents, see the VARIABLE SPEED OPERATION section. For installation cost and available options, see the MOD CENTRAL section.
Restricted use	DO NOT APPLY THE FOLLOWING MOTORS ON VARIABLE FREQUENCY DRIVES: Single Phase motors, Motors with inherent overload protection, Multi-Speed motors, Motors with 1.0 Service Factor on sine wave power. Fire Pump motors should not be used with variable frequency power supplies, due to the critical nature of these applications.
Hazardous Locations	Consult with Marathon Motors when applying motors and drives into Hazardous Locations, either Division/Zone 1 or Division/Zone 2 areas. UL and CSA policies prohibit the installation of bearing protection devices, such as shaft grounding brushes, rings or insulated bearings on motors in Hazardous Locations.

## Maximum Cable Lengths from the Motor to Drive

PRODUCT DESCRIPTION	3 kHz CARRIER FREQUENCY (PHASE TO PHASE)*		
	230 VOLT	460 VOLT	575 VOLT
56-326 NEMA, 100-225 IEC Frames	600 ft.	125 ft.	40 ft.
364-5013 NEMA, 250-315 IEC Frames	1000 ft.	225 ft.	60 ft.
Motors with CR <sup>200</sup> Corona Resistant Magnet Wire	1500 ft.	475 ft.	140 ft.
Motors with MAX GUARD <sup>®</sup> insulation system	Unlimited	Unlimited	650 ft.
Form-wound low voltage motors	Unlimited	Unlimited	650 ft.

\* Higher carrier frequencies require shorter cable length to obtain normal (50Khrs) insulation life.

## Standard Motor Insulation Systems

CR200 CORONA-RESISTANT MAGNET WIRE	Max Guard <sup>®</sup> *
microMAX <sup>®</sup> inverter duty "4 - in - 1" Three Phase, C-Face with Removable Base Standard Three Phase stock Brakemotors Blue Chip <sup>®</sup> Severe Duty Explosion Proof, EPAAct Efficiency Max +	Black Max <sup>®</sup> Vector Duty - All Product Blue Max <sup>®</sup> Vector Duty - All Products PowerWash <sup>™</sup> XT, SXT, and SXT-Plus Washdown Duty - Three Phase Blue Chip <sup>®</sup> XRI Severe Duty Blue Chip <sup>®</sup> XRI-841 (IEEE841 compliant) Automotive Duty "T" Frame Blue Chip <sup>®</sup> Explosion Proof, XRI <sup>®</sup> Premium Efficiency Globetrotter <sup>®</sup> IEC Metric motors

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## VARIABLE SPEED INFORMATION

Marathon Motors Vector-Duty and Inverter-Duty motors, unless otherwise stated, are rated for continuous operation in a 40°C ambient and for altitudes up to 3300 feet (1000 meters) above sea level. Special application considerations, such as high or low ambient, intermittent ratings, high altitude, duty cycle rated, extended constant horsepower range, special base speed, voltage or frequency, or any other special requirements, should be reviewed by a factory representative.

It is the responsibility of the startup personnel during commissioning of the VFD/motor system to properly tune the drive to the motor for the specific application. The correct voltage boost and volts/hertz settings are application dependent and unique to each motor design. Procedures for these adjustments should be in your VFD user manual. Many Vector Duty and Inverter Duty motors in this catalog are equipped with thermostats; warranty coverage may be denied if they are not properly utilized.

**WARNING** Power factor correction capacitors should never be installed between the drive and the motor.



## INVERTER DUTY OR INVERTER RATED

“Inverter Duty” (often called “Inverter Rated”) motors are suitable for use with Variable Frequency Drives, as long as operation is within the application guidelines published in this catalog. In general, Marathon Motors’s three phase, general purpose, NEMA Design B motors are considered “Inverter Duty”, and meet or exceed the requirements of NEMA MG1, Part 30. As required under Federal law, these motors comply with EPAAct efficiencies when operating from utility power.

Many of Marathon’s motor product lines have been enhanced to facilitate reliable operation on today’s variable speed drives, including wider constant torque speed range (up to 20:1) and improved insulation systems that withstand voltage spikes common with variable frequency operation.

Inverter Duty (Rated) motors are most often used in 10:1 speed range, variable torque or constant torque applications. A vector control is usually required for operation beyond 10:1 CT.

Refer to “Guidelines for Application of General Purpose, Single Speed Three Phase Motors on Variable Frequency Drives” in this section of this catalog for the allowable speed range and cable length restrictions (from VFD to motor). Additional detail regarding a specific product’s capabilities is available on its catalog page, or by consulting your application engineer.

**VECTOR DUTY** – “Vector Duty” describes a class of motors that are used in conjunction with Open- (without encoder) or Closed-Loop (with encoder) Vector controls, that provide enhanced performance under low speed operating conditions, or in cases where torque (rather than speed) must be controlled. “Vector Duty” motors can be applied to Volts/Hertz (scalar) drives, as well.

Marathon Motors’s “MAX” family, consisting of Blue Max®, Black Max® and microMAX™ motors, have been specifically designed for optimal operation on vector or volts/hertz controls. These motors feature a wide constant torque (up to 2000:1) and/or constant horsepower (up to 4:1) speed range and are performance-matched to all current technology IGBT drives. Vector Duty motors meet or exceed the requirements of NEMA MG1, Part 31, and are equipped with an enhanced insulation system (MAX GUARD® or CR<sup>200</sup>) to provide many years of trouble-free service. Consult the catalog page for each product’s capabilities and features. As these motors are specifically designed for operation through an inverter, they are exempt from EPAAct legislation. Model numbers contain the letter “H” in the “Electrical Type” field.

**VARIABLE TORQUE LOADS** – Applications include fans, blowers and centrifugal pumps. Torque varies as the square of the speed, and horsepower as the cube of the speed. Operation below base speed significantly lightens the load on the motor. While most variable torque applications do not require the motor to operate below half speed, the motor is fully capable of operation to zero speed. Operation above base speed significantly adds to the load on the motor; therefore, a factory representative must review applications requiring variable torque above base speed. Refer to the application chart found on page 14 for use of general purpose three phase motors on variable frequency drives. Marathon’s microMAX™, Black Max® or Blue Max® motors are not necessarily required for operation of variable torque loads. A bypass circuit is often employed in Variable Torque applications. If this device is intended to be used, selection of a NEMA Design B motor is recommended, to withstand the inrush current during across-the-line starting.

**CONSTANT TORQUE LOADS** – Applications include conveyors, elevators, hoists, extruders, positive displacement pumps, mixers and converting equipment. Torque remains constant throughout the range of operation, and extra care should be taken in the proper application of motors, especially at very low speeds. Most constant torque applications don’t require operation below 10:1 (i.e. 6 Hz operation on a 60 Hz motor), but an increasing number of applications historically reserved for servo and/or stepper systems are being served with motors capable of operation beyond 20:1, up to 2000:1 (zero speed, constant torque). Refer to the application chart found on page 17 for use of general purpose three phase motors on variable frequency drives.

Continued on next page.

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## CONSTANT TORQUE LOADS (Cont'd.)

Applications requiring greater than 20:1 C.T. are ideal for microMAX™, Black Max® or Blue Max® motors. These motors provide full rated torque within their listed speed range, without exceeding a Class F temperature rating while under inverter power (many operate at Class B). Ratings in this catalog have been developed, based on extensive testing on IGBT inverters, set at a minimum 3 KHz (or equivalent) carrier frequency.

Vector Duty and Inverter Duty motors from Marathon Motors are designed for operation at 150% of rated load for one minute, up to the base speed of the motor (overload capability declines to 100% as the motor reaches maximum constant HP speed). These motors accommodate constant horsepower operation to 1-1/2 to 2 times base speed, subject to the motor's maximum safe mechanical speed limit. Refer to the Maximum Safe Mechanical Speed Chart, as well as the performance section for each motor's capability.

Motors rated for zero RPM continuous duty (1000:1 or 2000:1) must be powered by vector drives to produce rated torque without overheating. Optimum zero speed and low-speed full torque performance may require a closed loop vector drive (with encoder feedback).

**CONSTANT HORSEPOWER LOADS** – Applications include coil winders, band saws, grinders, and turret lathes. Operation requires the motor to deliver the same horsepower rating, regardless of shaft speed. Torque increases at low speed and decreases at higher speed. Most general purpose motors can deliver constant horsepower up to 1 1/2 times base speed (consult a factory representative to verify performance). However, many constant HP applications require operation to twice base speed, and some, such as coil winders, up to 4 times base speed. microMAX™, Black Max® and Blue Max® motors are designed for 1 1/2 to 2 times base speed, and the Wide CHP motors, found in Marathon's SB371 Catalog, deliver up to 4 times constant horsepower performance.

**BEARING CURRENTS** – As stated in NEMA MG1-31.4.4.3, to protect a motor from inverter-sourced shaft voltages, either both bearings must be insulated or the motor shaft must be effectively grounded. Marathon Motors offers several effective means to protect the bearings from inverter sourced EDM (electrical discharge machining). A Shaft Grounding device is standard in Blue Max® motors, in frame sizes 444T and larger. Insulating the motor bearings will not prevent damage to bearings of a connected load, and insulated couplings should be employed to protect the load. Adding a ground brush to a motor with insulated bearings will divert motor shaft currents and help protect the bearings of the connected load. At this time, UL policy prohibits the use of ground brushes or insulated bearings in Hazardous Locations (Div 1 & 2, Zones 1, 2, 21 & 22).

### The Marathon Solution to Bearing Currents

Any motor with a "-P" behind the catalog number and a "P" footnote features a current mitigation device.



**MOTOR GROUNDING** - Frames and accessories of all motors must be grounded in accordance with the National Electric Code (NEC) Article 430. Refer to NEC Article 250 for general information on grounding. Proper grounding of inverter-driven motors is essential to protect personnel and livestock from inverter-sourced common mode voltages, which may reach hazardous levels on the frame of ungrounded or poorly grounded motors.

**LOW INPUT VOLTAGE** – If, due to lower utility supply voltage, the input voltage from the VFD to the motor is lower than the motor's rated voltage, de-rating of the motor's base frequency, horsepower, full load RPM, and constant HP RPM is required. The revised values can be calculated by multiplying by the ratio of the voltage change. For example, to operate a 460 volt motor from an inverter fed by 50 or 60 HZ, 400 volt utility power, the multiplier is 400/460 or 0.87.

The VFD can be reprogrammed to match the new base point values, allowing the motor to provide rated torque at rated current from the new base speed down to its original minimum Constant torque speed. The motor's CHP range will begin at the new base frequency and will be shortened by the same ratio as described above.

**OVERSPEED CAPABILITY** – Maximum safe mechanical speed capability is a function of bearing size and type, lubrication, rotor balancing technique and specifications, air gap, enclosure, frame construction and connection to the driven load. In addition, consideration must be given to ambient noise levels, as operation above base speed will increase motor noise and vibration, and reduce bearing life. Under no circumstances should bearing hub temperature exceed 100°C. Belted loads should not exceed 60 Hz operating RPM by more than 25% (NEMA "TS" shafts are not suitable for belted loads). Due to external cooling fans, TEFC (and Explosion Proof Fan Cooled) motors are limited to 4000 RPM maximum speed.

Marathon Motors, through extensive testing in our state-of-the-art laboratory and in actual field experience, has developed a number of high speed motors whose maximum safe mechanical speed exceeds the values in the table below. The following table depicts maximum safe speed limits for continuous operation, direct-coupled, non-explosion proof motors, and does not imply constant horsepower capability. Please consult a factory representative for requirements beyond those listed, or for intermittent duty limits.

**Maximum Safe Mechanical Speed Limits  
(ODP, TENV, DPV OR TEBC ENCLOSURES)  
60 Hz base frequency**

Frame Size	2-Pole	4, 6 or 8-Pole
56-184	7200	5400
213-256	5400	4200
284-286	5400	3600
324-326	4000	3600
364-365	4000	2800
404-449	3600	2800
5000 Fr	N/A	CALL
6800 Fr	N/A	CALL

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## OTHER APPLICATION CONSIDERATION

For proper selection, the following should be considered:

- Horsepower or torque requirements at various speeds.
- Desired speed range of the load and motor.
- Acceleration and deceleration rate requirements of the process being controlled.
- Starting requirements including the frequency of starting and a description of the load (reflected inertia at the motor, load torque during starting).
- Whether the application is a continuous process or duty cycle of starts, stops and speed changes.
- A general description of the type of application including the environment in which the VFD system components must operate (determines motor enclosure and/or explosion proof classification).
- Description of the available electrical power supply and wiring.
- Special performance requirements, if any.
- Whether the drive will be configured with a by-pass circuit. In case of its deployment, the motor will operate like its fixed speed counterpart and may require a NEMA B design which limits in-rush current, or selection of a larger motor starter or other protective circuitry.
- Load sharing
- Mounting and other mechanical considerations

VARIABLE SPEED OPERATION

## Typical Temperature Rise Of Various Enclosures

Temp. Rise

