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AC Motors In-Depth

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Keys to Successful Motor Operation

A high quality motor

Understanding the application

Proper motor selection

Proper installation

Proper maintenance

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Siemens Premium Quality Motor

Full cast iron construction

Bearing protection

Low noise

Solid cast dynamically balanced rotor

Guaranteed vibration levels

Class F insulation

Low magnetic losses

Application and Selection Considerations

Motor torque and load requirements

Starting method

Voltage and frequency variations

Duty cycle

Enclosures

Insulation

Temperature rise and service factor

Motor Torque and Load Requirements

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An AC motor is a torque generator

Shaft Power = (Torque)X(Speed)/(5250)

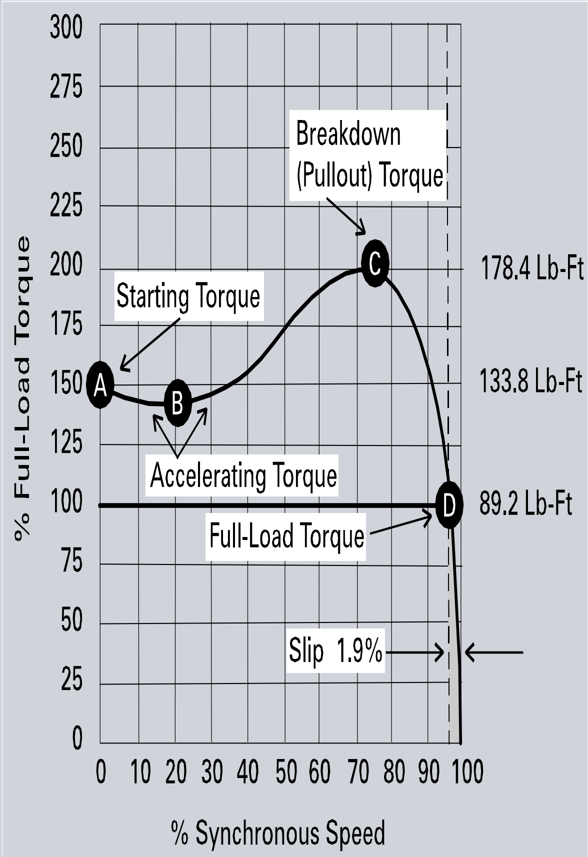
- A motor operated above rated load will generate more heat and have a higher temperature rise
- NEMA specifies standard inertia values for each motor rating
- A common misconception that high LRT ensures successful starting only results in a motor that runs hotter with poor efficiency
- Best way to evaluate torque requirements is to superimpose the speed-torque curve of the driven equipment onto the speed-torque curve of the motor

Speed-torque Curve

NEMA has established torque requirements for three basic motor designs: B, C and D

The most important torque points are:

- Starting (Locked Rotor) Torque
- Accelerating Torque
- Breakdown Torque
- Full Load Torque



Screw Down Actuator

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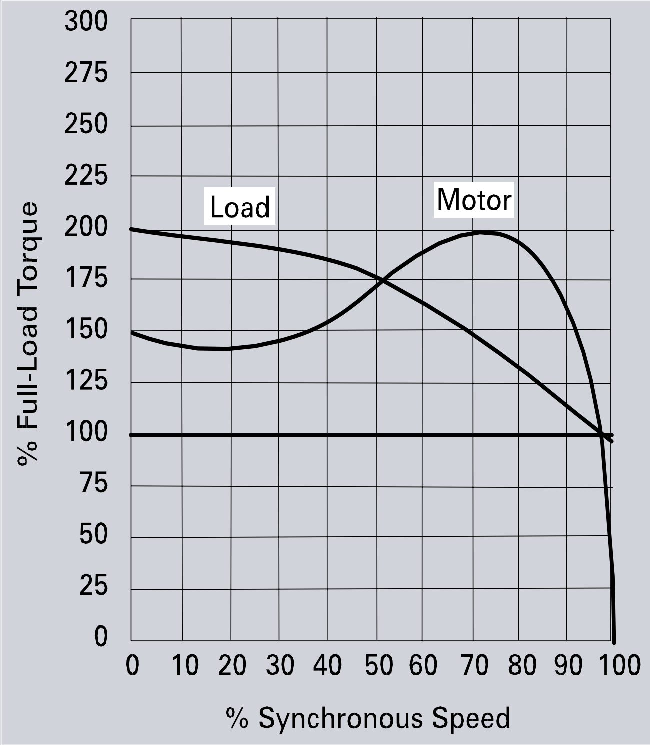
Starting torque approximately 200%

NEMA B motor will not start the load



Speed-torque Curve

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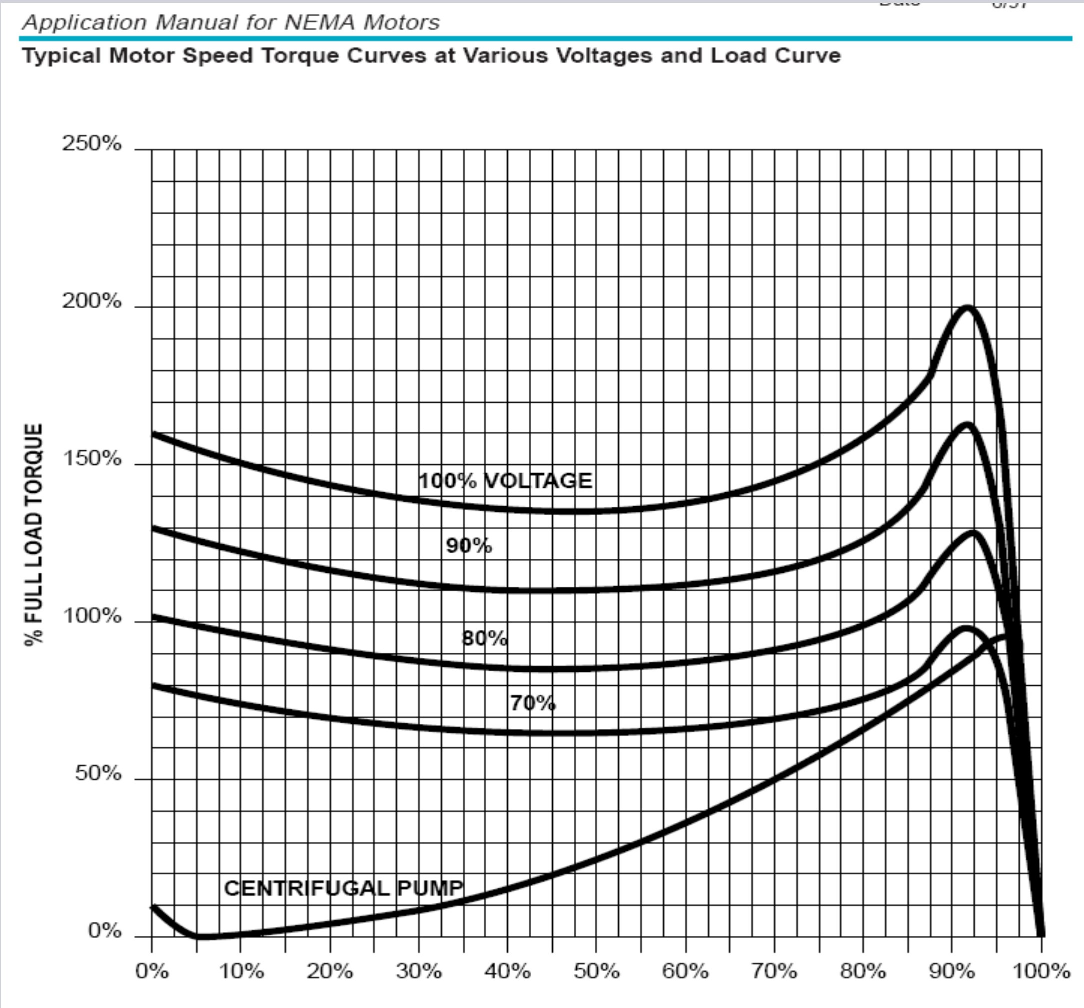

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Starting Method

Preferred method is “across the line” or DOL

- Full voltage applied
- Provides maximum torque for acceleration
- Draws 6-7 times the full-load current

Alternative starting methods

- Reduced voltage start
- Autotransformer
- Wye-Delta winding
- Two-part Winding

Starting Method

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Type of Starting	Relative Starting Current	Relative Starting Torque	Relative Smoothness of Acc.	Allowable Acc. Time
ATL/DOL	100%	100%	Smoothest	N.A.
Resistor/Reactor (at 65% voltage)	65%	65%	2nd smoothest	5-15 s
Autotransformer (at 65% voltage)	42%	42%	3rd smoothest	30 s
Wye-Delta	33%	33%	4th smoothest	45-60 s
Two-Part	50%	50%	Least smooth	2-3 s

Voltage and Frequency Variations

Fluctuations in voltage or frequency lead to premature winding failure due to heat buildup

NEMA sets limits on variation

- ± 10% voltage at rated frequency
- ± 5% frequency at rated voltage
- Maximum 10% (absolute values) combined with 5% limit on frequency
- Over-frequency results in overloading the motor
- Under-frequency results in inefficient cooling

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Voltage and Frequency Variations

Incorrect voltage

- Operating above rated voltage increases core losses thus reducing efficiency
- Operating below rated voltage, motor draws more current and overheats

Unbalanced voltage

- A 1% imbalance in voltage can lead to an 8% imbalance in current
- Hot spots are produced while net torque is reduced
- Generally, 10°C rise cuts motor life in half

Duty Cycle

Siemens motors are suitable for continuous duty

Repetitive starts and stops

- At start motor draws 6 to 7 times normal current
- Two cold starts in succession or one hot start is not detrimental
- For random wound motors, NEMA allows 5000 lifetime full voltage starts

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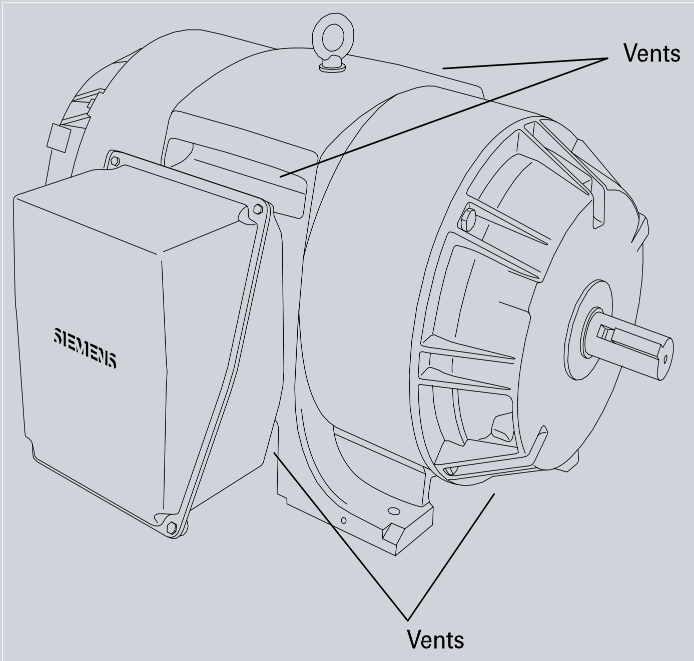
Enclosures

Most motors are built to last at least 20 years

Life will be shortened if motor is not protected from the environment

Difference between open and enclosed enclosures is the degree of protection given to the windings

Open Drip Proof



Particles approaching motor within 15 deg of vertical cannot enter motor body

Suitable for indoor installation

Totally Enclosed Non-Ventilated

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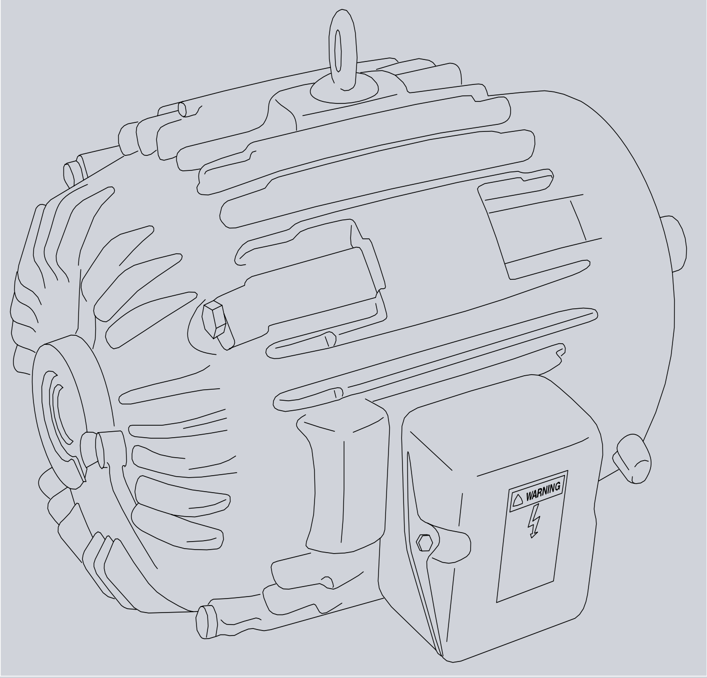
Restricts free exchange of air between inside and outside

Heat is dissipated through conduction

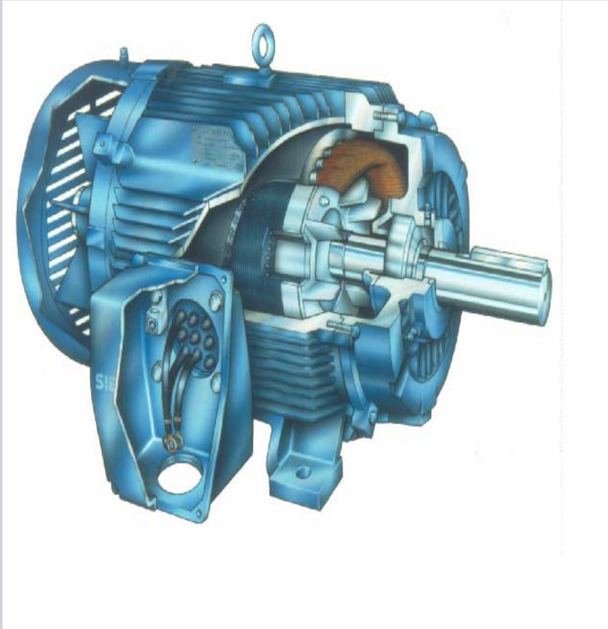
Suitable for indoor/outdoor installation



Totally Enclosed Fan Cooled

TEFC is similar to TENV with addition of a fan

Can be used in dirty, moist, or mildly corrosive conditions



Insulation

Stator leads, coils and connections are covered with a dielectric insulation

Stator is subjected to dip/bake cycles for low voltage motors

Low voltage motors utilize random wound coils

Under ideal conditions, insulation system can be expected to have life cycles in excess of 100,000 operating hours

Insulation is classified according to total temperature capability of the system

Temperature Capability of Insulation System

Insulation Class	Maximum Temperature (in degrees C)
A	110°
B	130°
F	155°
H	180°

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Temperature Rise and Service Factor

INSULATION CLASS	SERVICE FACTOR	TEMP RISE	RELATIVE LIFE*
B	1.0	80	1.0
B	1.15	90	2.8
F	1.0	105	5.7
F	1.15	115	1.0
F	1.0	80	11.0

CLASS B - 130^{o} C TOTAL LIMIT
CLASS F - 155^{o} C TOTAL LIMIT

For every 10°C above the insulation class thermal limit a motor is operated, the insulation life expectancy is reduced by as much as 50%.

Proper Motor Installation

Unusual service conditions

Ambient temperature

Altitude

Alignment

Belt tension

Ventilation

Unusual Service Conditions

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Exposure to the following:

- Combustible, explosive or abrasive dust
- Chemical fumes, nuclear radiation
- Lint or flying fibers
- Steam, salt-laden air or oil vapor
- Damp locations conductive to growth of fungus
- Shock or vibration

Operation in the following conditions:

- Excessive departure from rated voltage or frequency
- Ungrounded power system
- Frequent starts and/or overspeeds

Ambient Conditions

Motors are designed for an ambient temperature of 40° C

- A higher ambient temperature results in higher motor operating temperature
- A higher class of insulation or oversized motor overcomes this problem
- If ambient temperature is well below 40° C, motor output can be increased

Ambient Conditions

Motors are designed for a minimum ambient of -25° C

- Lower minimum ambients can require special materials of construction depending on minimum ambient required
  - Low temperature grease
  - Stainless steel hardware
  - Stainless steel eyebolt
  - Special shaft material
- Siemens does not have UL certification for explosion proof motors below -25° C

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Altitude

Motors are designed to operate at or below 3300 ft ASL

- Higher altitudes dissipate less heat
- Class F insulation class is suitable for high altitudes
- Recommended derating factors:

3%	3300 – 5000 ft
6%	5000 – 6600 ft
10%	6600 – 8300 ft
14%	8300 – 9900 ft

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Alignment

Dimensional limitations

- Distance from shaft centerline to mounting feet (adapter base)
- Job site obstructions
- Location of conduit box

Suggested alignment tolerances for direct-coupling

(Mils)	RPM	Installation	In Service
Soft Foot		All	±1.0
±1.5			
Parallel Offset	1200	±1.25	±2.0
	1800	±1.0	±1.5
	3600	±0.5	±0.75

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Belt Tension and Ventilation

Accurate belt tension is critical to belt life and motor life

Unclean or confined conditions inhibit proper ventilation

- Obstructions placed near motor may deflect air back into the inlet
- Noise reduction enclosures restrict ventilation
- Windings overheat
- Thermal life is shortened

Motor Maintenance

Bearing lubrication

Cleaning

Testing

Motor protection

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Bearing Lubrication

Excess grease can be forced out of the bearing housings and into the motor windings

- Results in winding failure, reduced bearing life and reduced motor efficiency
- To prevent overgreasing, follow the motor manufacturer's lubrication instructions and specifications
- If bearings cannot be lubricated, replace every five years (8 hr/day) or every two years (24 hr/day)

Additional Bearing Problems

Regreasing with incompatible grease

Misalignment

Faulty mounting practice

Incorrect shaft and housing fits

Ineffective sealing

External vibration sources (including while bearing is not rotating)

Electric current passing through bearing

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Cleaning

Dirt and debris can accumulate inside motor and deteriorate insulation / windings

Air passages must be kept clean to dissipate heat

TEFC motors require more cleaning

- Fan covers can accumulate debris reducing proper cooling
- Cooling fins must be kept clean to dissipate heat from the motor

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Testing

Complete log of tests and inspections should be maintained

- Insulation resistance test
  - Test should be conducted annually, recorded and compared with future readings (“trending”)
  - Windings should be at room temperature
  - For motors 600V and below, 500-volt megohmmeter should be used
- Vibration test
  - Help detect bearing wear, mechanical looseness, misalignment, defective belts or rotors, electrical unbalance, etc.

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Motor Protection

Thermal Protection

- Thermistors
- Thermostats
- Resistance Temperature Detectors

Bearing temperature monitoring

Vibration monitoring

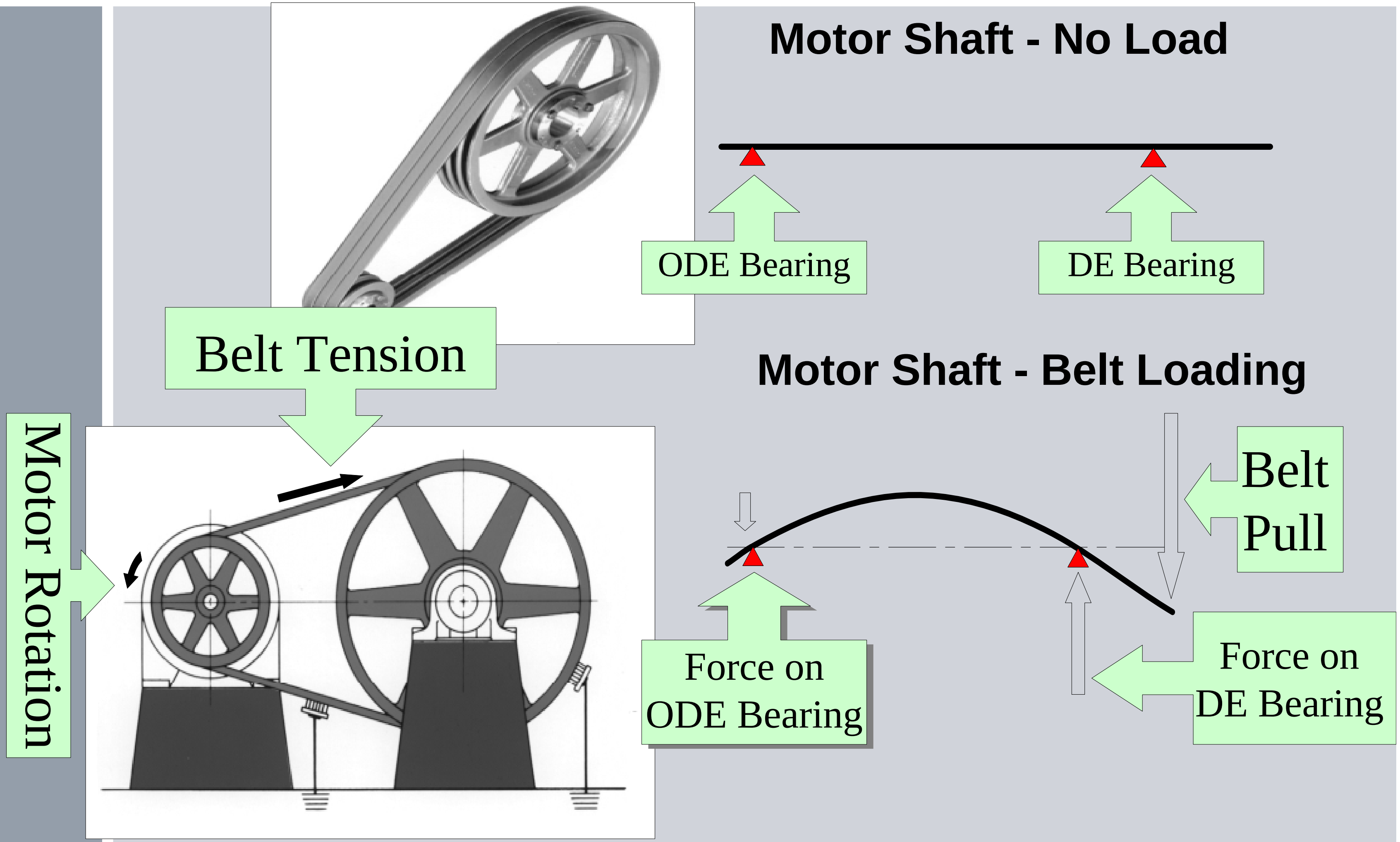
Moisture protection

- Install space heaters
- Apply low DC voltage to one phase of motor windings

Belting Applications

Misapplication of motors in belted service can lead to premature failure of the bearings and/or shaft

Belting Applications



Belting Applications

To evaluate belting applications, need the following information:

- Number and size of belts
- Motor and driven sheave diameters
- Distance between the centerlines

Application may require special bearings for increased bearing life

- Roller bearings on motors normally supplied with ball bearings
- Larger than standard bearings for motors normally supplied with roller bearings

Application may require special shaft material for increased shaft strength

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Belting Applications

Considerations:

- Large diameter motor sheaves are good for the motor (lower bending moment acting on shaft)
- Small diameter motors sheaves are bad for the motor (higher bending moment acting on shaft)
  - Minimum sheave diameter information provided on page 8-29 of 2008 price catalog and in the NEMA Motor Application Manual
- Wide sheaves (excessive # of belts) are bad for the motor
  - Moves the center of the radial force further from the DE bearing (higher bending moment on shaft)

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Belting Applications

Other considerations:

- 2-Pole (3600RPM) motors not recommended for belting applications (> 25 HP)
  - Generally limited by speed capability of bearings and excessive tension needed due to centrifugal force on the belts
  - NEMA does not address 2-pole, belted applications (> 25 HP)
- Mounting of the motor
  - Roller bearing motors mounted vertically, shaft down require a special grease path so that grease is applied above the bearing
- Roller bearings can be used in horizontal, direct connect applications (not recommended) if customer OK with the grumbling bearing noise that results
- Roller bearing motors should never be used in a vertical, direct connect application as rotor weight is needed to put minimum radial load on bearing.

Typical Motor Applications

Centrifugal pumps, blowers and compressors

Chippers and crushers

Centrifuges

Large fans

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Typical Motor Applications

Centrifugal pumps, fans and blowers

- Least demanding applications for motors
- Variable torque applications
- Low inertia

High inertia applications

- Chippers and crushers
- Centrifuges
- Large Fans
- Often good candidates for soft starting

Definite Purpose Motors

Two-speed motors

Vertical P-base motors

NEMA Design C motors

Brake motors

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Definite Purpose Motors

Two-speed motors

- Commonly used in cooling tower (fan) applications
- Two types of applications
  - Variable torque
  - Constant torque
- Two types of configurations
  - Single winding (low speed must be ½ of high speed)
  - Two winding (lower cost controls)

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Definite Purpose Motors

Vertical, P-base motors

- Motors are designed to carry axial thrust
- Used in vertical pump applications
- Types of configurations
  - Standard P-base configuration (HP frames)
    - Thrust bearing can be located on DE or ODE depending on design
  - In-line P-base configuration (LP frames)
    - Thrust bearing located on ODE
    - Can carry higher thrust loading than normal thrust HP frames
  - Hollow shaft configuration (TP frames) – no longer offered

Definite Purpose Motors

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NEMA Design C motors

- Have higher locked rotor (starting) torques than NEMA Design B motors , but slightly lower BDT
- Common uses include loaded conveyor applications

Brake Motors

- Integrally-mounted on NDE to stop motor in applications where coasting to a stop is not desired
- Common uses include material handling
- Not recommended for high inertia applications

Questions