
Electrical Level 2
Motors: Theory and Application 26202-14

Objectives

When trainees have completed this lesson, they should be able to do the following:

1. Define the following terms:
    - Controller
    - Duty cycle
    - Full-load amps
    - Interrupting rating
    - Thermal protection
    - NEMA design letter
    - Overcurrent
    - Overload
    - Power factor
    - Rated full-load speed
    - Rated horsepower
    - Service factor
2. Describe the various types of motor enclosures.
3. Explain the relationships among speed, frequency, and the number of poles in a three-phase induction motor.
4. Define percent slip and speed regulation.
5. Explain how the direction of a three-phase motor is changed.
6. Describe the component parts and operating characteristics of a three-phase wound-rotor induction motor.

Objectives and Performance Tasks

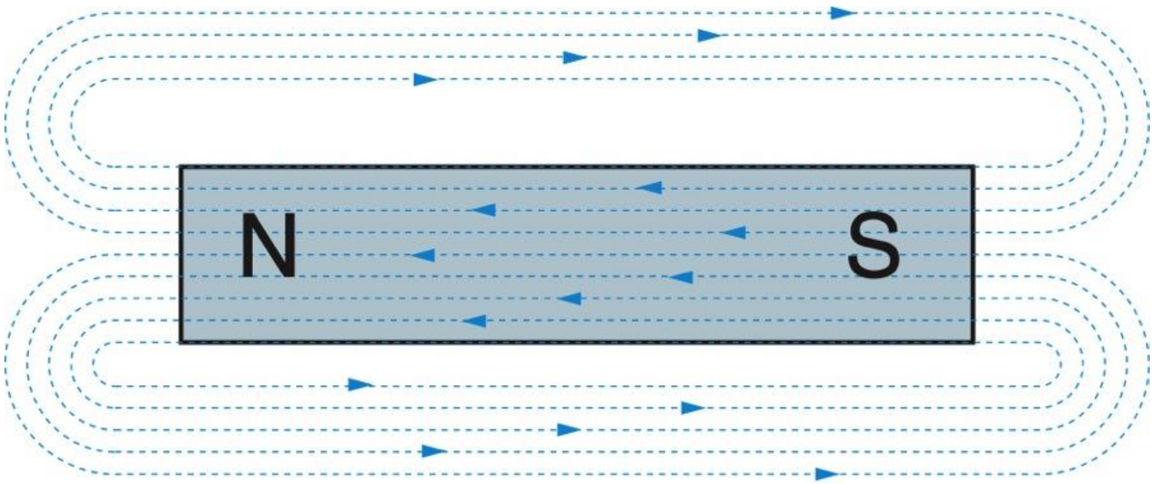
7. Describe the component parts and operating characteristics of a three-phase synchronous motor.
8. Describe the design and operating characteristics of various DC motors.
9. Describe the methods for determining various motor connections.
10. Describe general motor protection requirements as delineated in the *National Electrical Code®* (*NEC®*).
11. Define the braking requirements for AC and DC motors.

Performance Tasks

1. Collect data from a motor nameplate.
2. Identify various types of motors and their application(s).
3. Connect the terminals for a dual-voltage motor.

Introduction; DC Motor Principles

- Magnetic lines of force are continuous and form closed loops.
- Magnetic lines do not cross.
- Like forces repel, while unlike forces attract.



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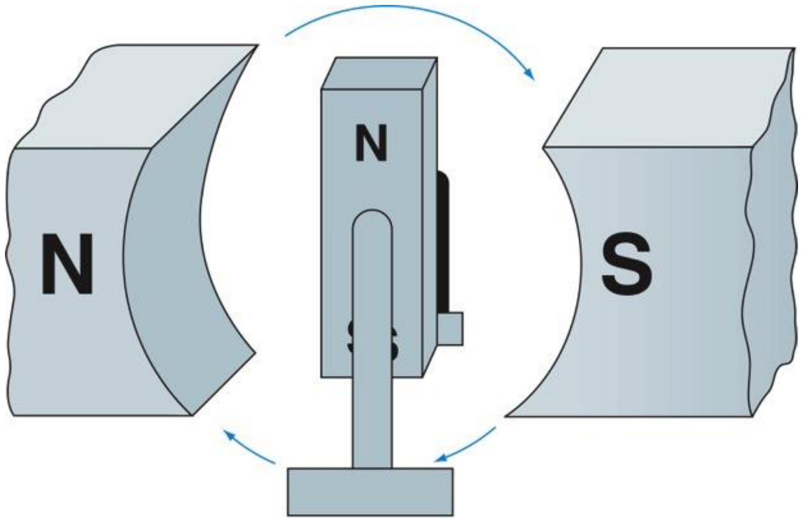
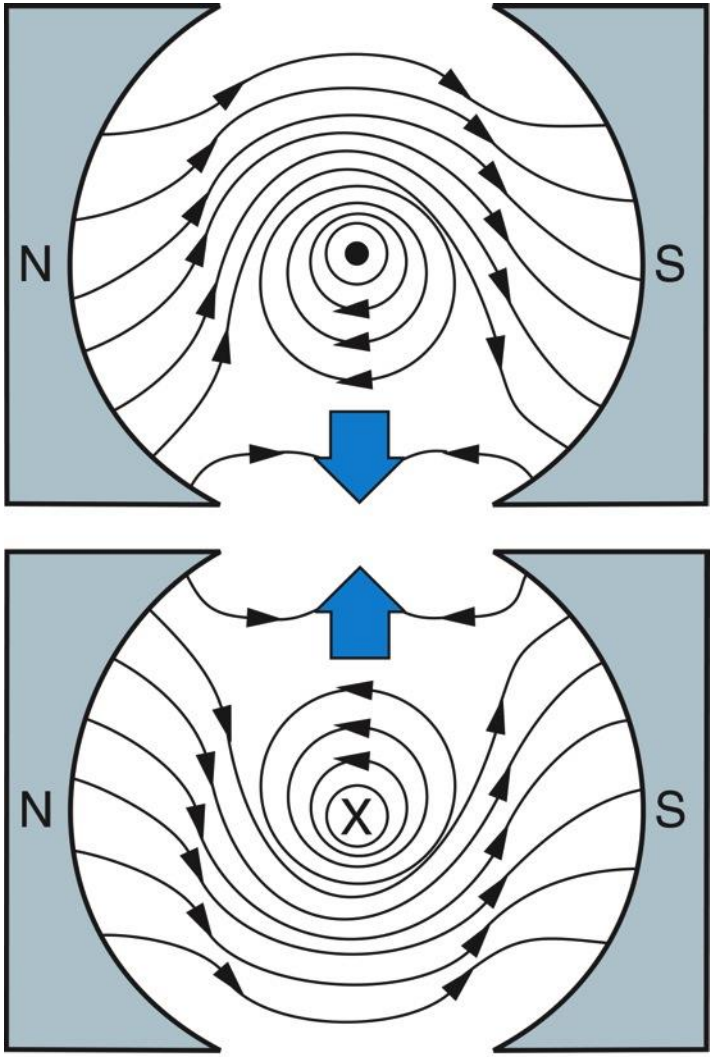
DC Motor Components

- The armature is a movable electromagnet located between the poles of another fixed magnet.
- The interaction between the two magnetic fields creates motor action.





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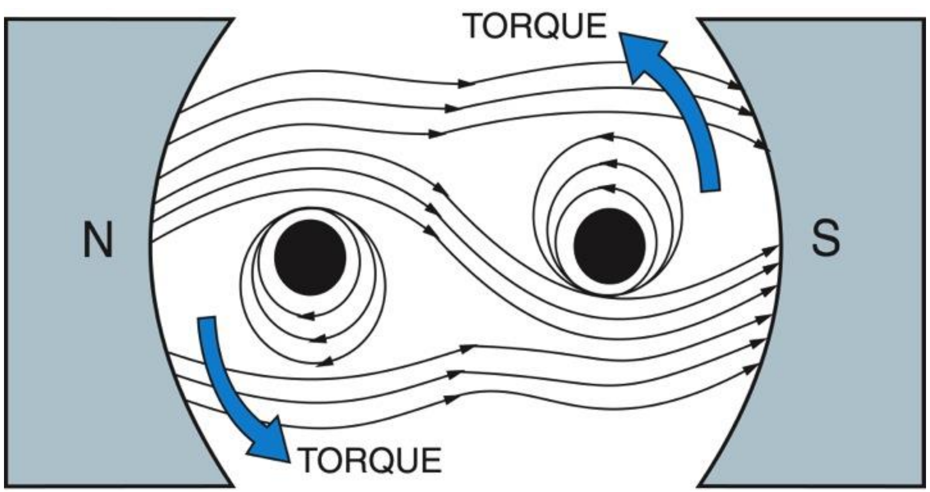
Motor Action

- When a conductor is placed in another magnetic field, the two fields can react to produce motor action.
- The conductor must be perpendicular to the magnetic field to achieve the maximum reaction.

Torque

- Torque is produced by mounting a loop in a magnetic field.
- Current is applied and the flux lines interact, causing the loop to act like a lever with a force pushing on its two sides in opposite directions. This results in a turning force known as torque.



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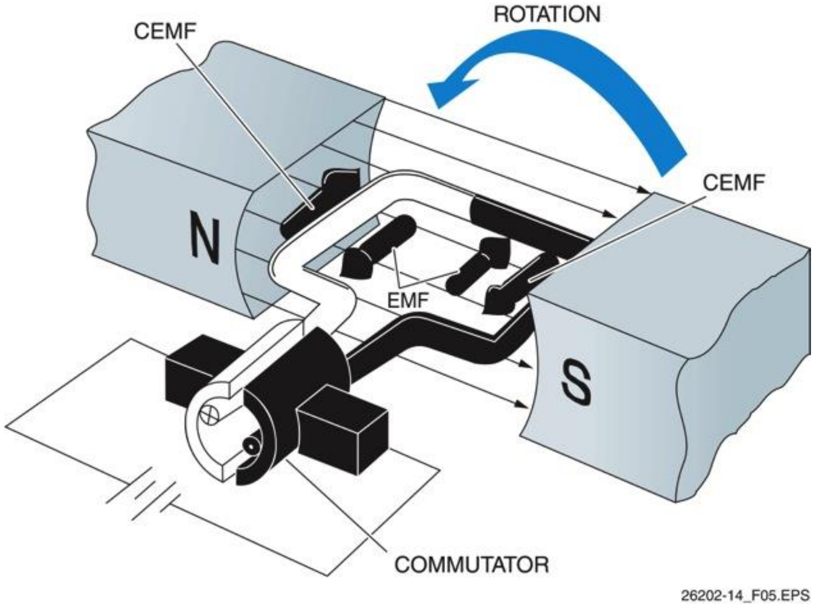
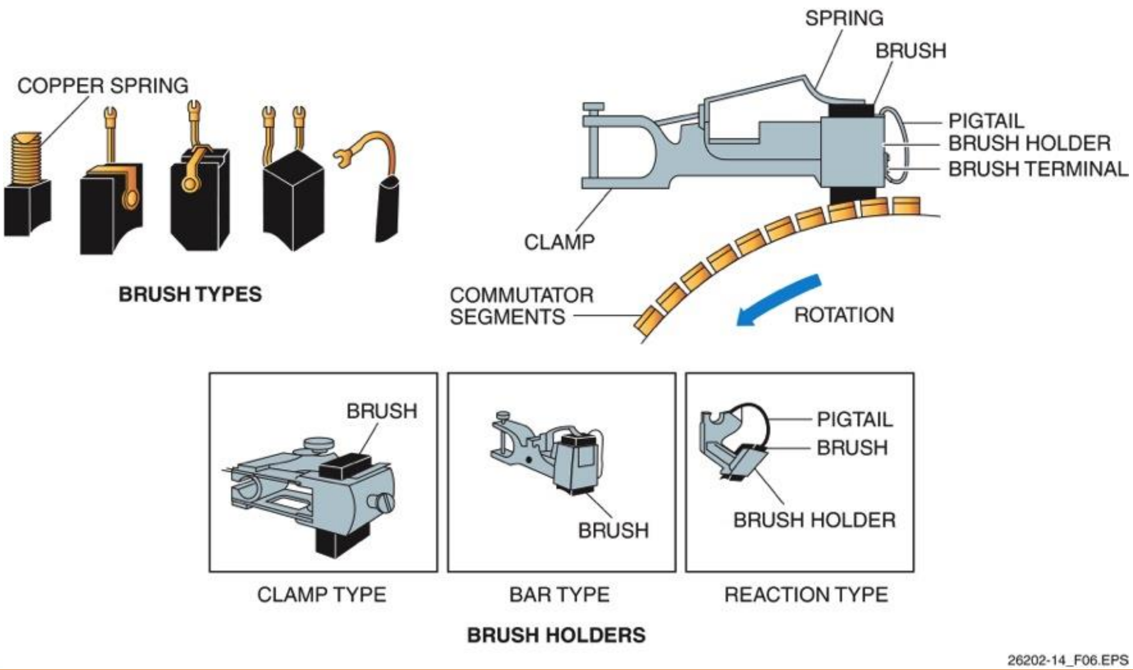
Single-Loop Armature DC Motor

- To produce rotation, the armature must be kept moving in the same direction by reversing the direction of current for every 180 degrees of rotation.
- This switching action is provided by a device known as a commutator.



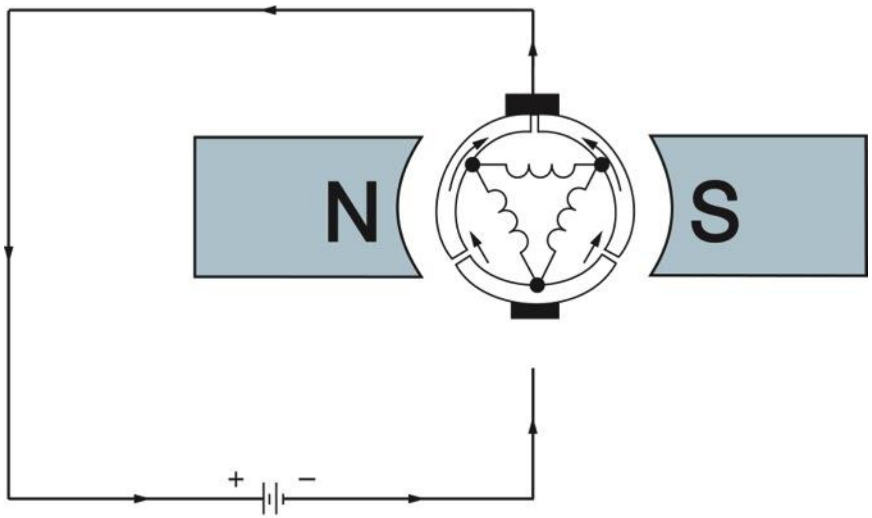
Brushes, Brush Rigging, and Commutator Connections

- A brush provides a connection between the movable commutator and the stationary power source.
- Various types of brushes and commutators are used in DC motors.



Self-Starting Motor

- If the armature stops in the middle of switching, the motor will not restart without turning the armature.
- A self-starting motor overcomes this by using multiple coils and commutator segments. Regardless of where the armature stops, there is always a path for current to restart the motor.



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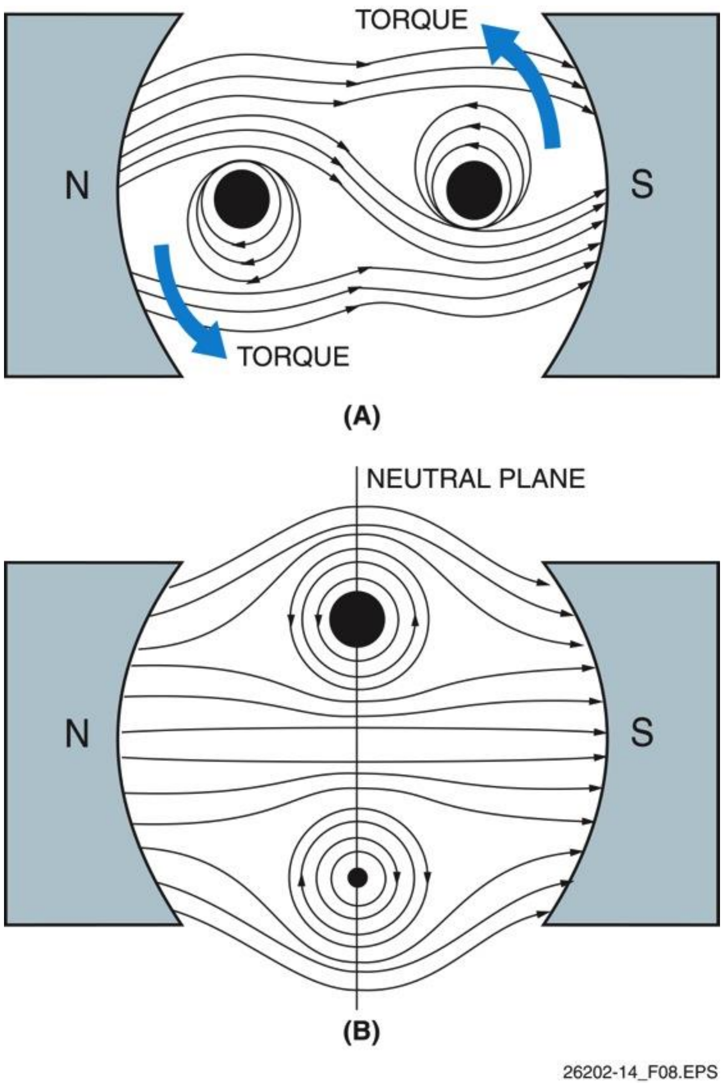
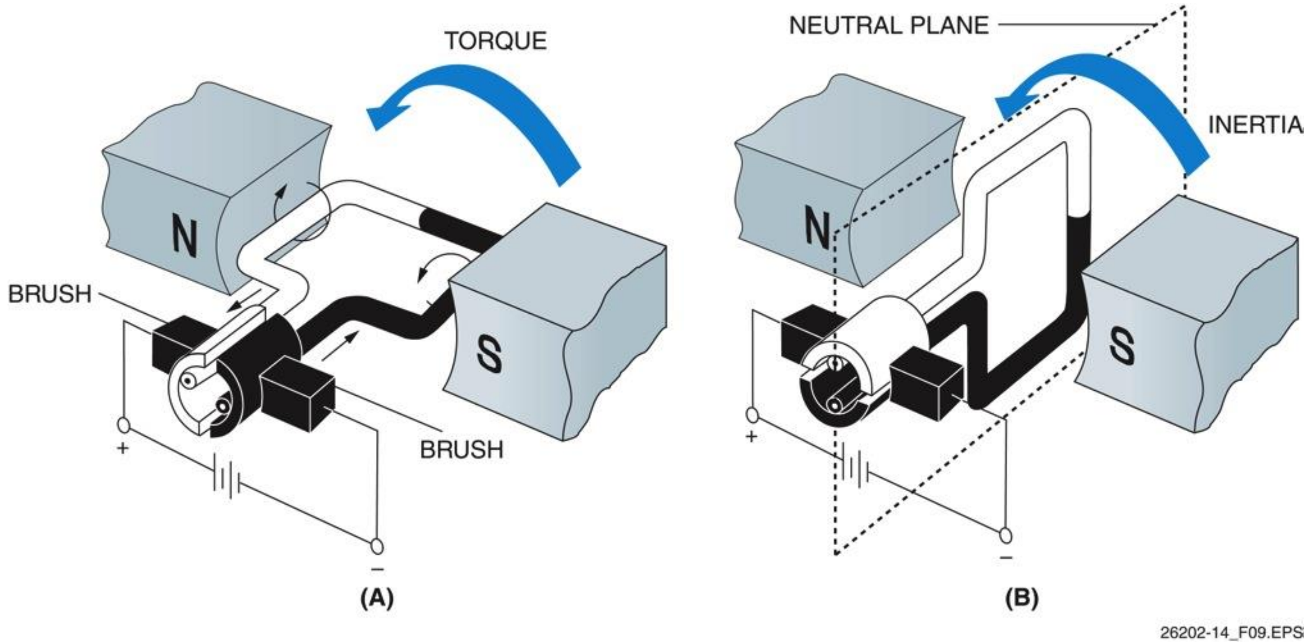


The Neutral Plane

The neutral plane represents the point in the armature rotation where there is no interaction between the magnetic fields.

Neutral Plane in a Single-Loop DC Motor

The force of inertia tends to push the armature past the neutral plane so the motor continues to operate. However, the inconsistent torque levels result in erratic operation and prevent the motor from being self-starting.



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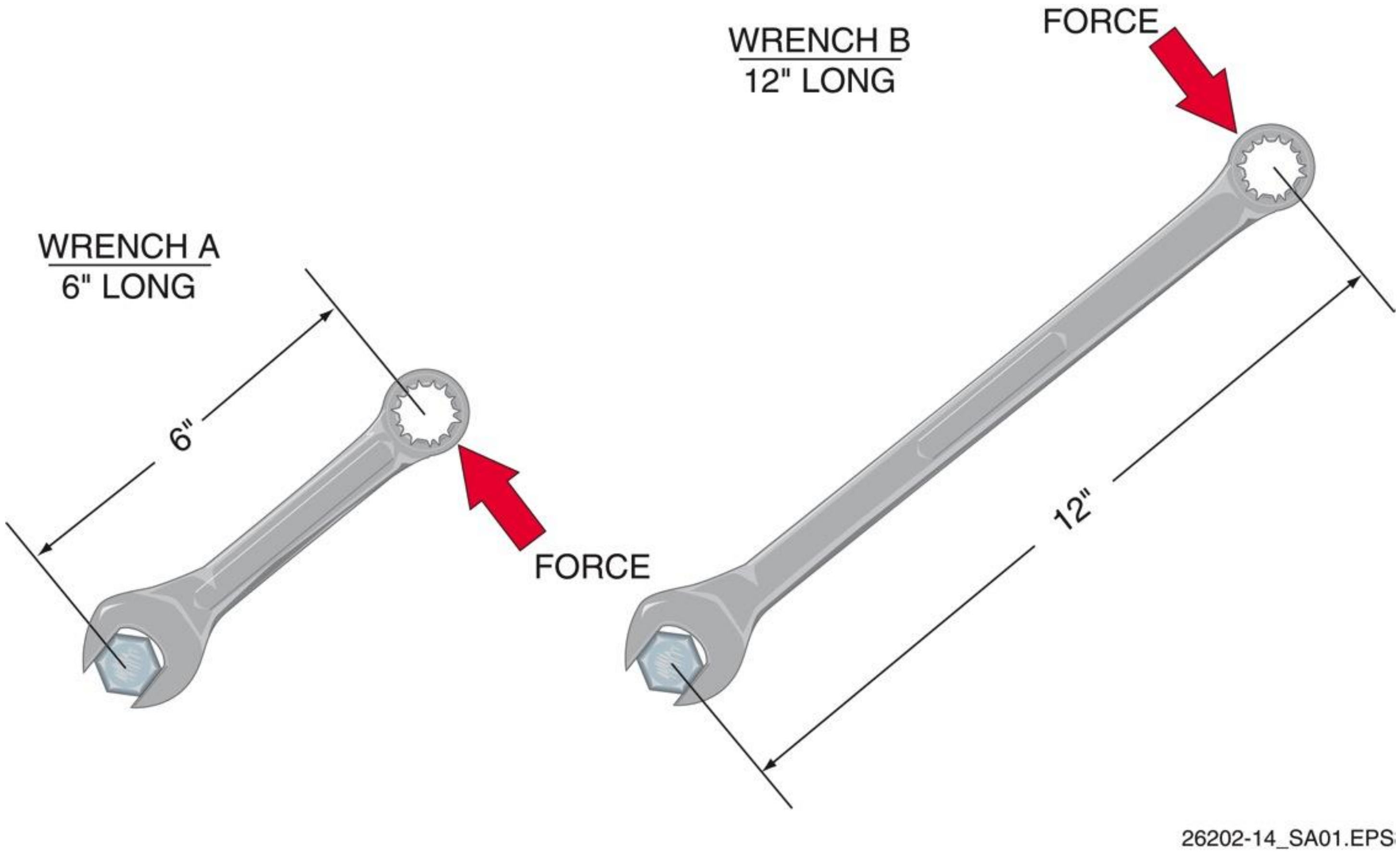
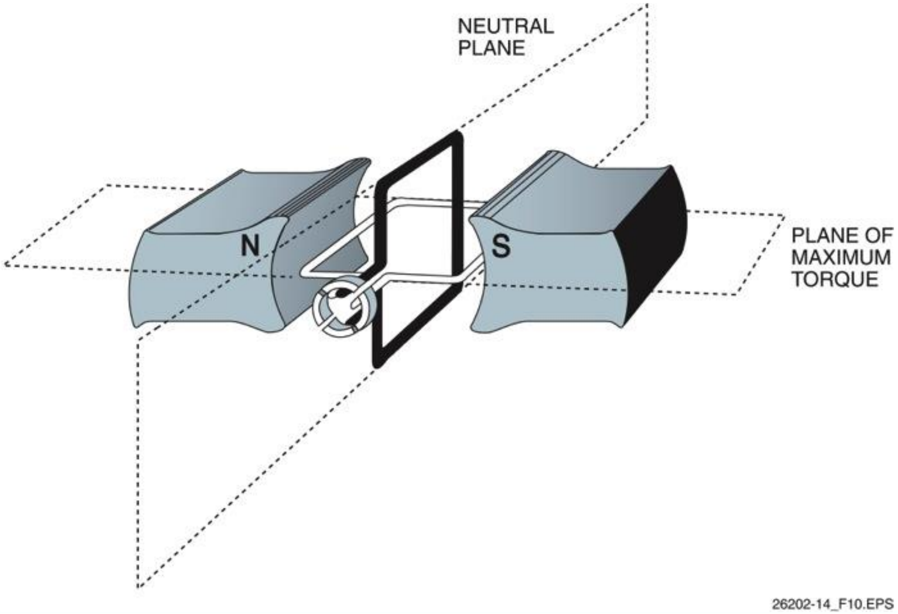
Understanding the Theory of Torque



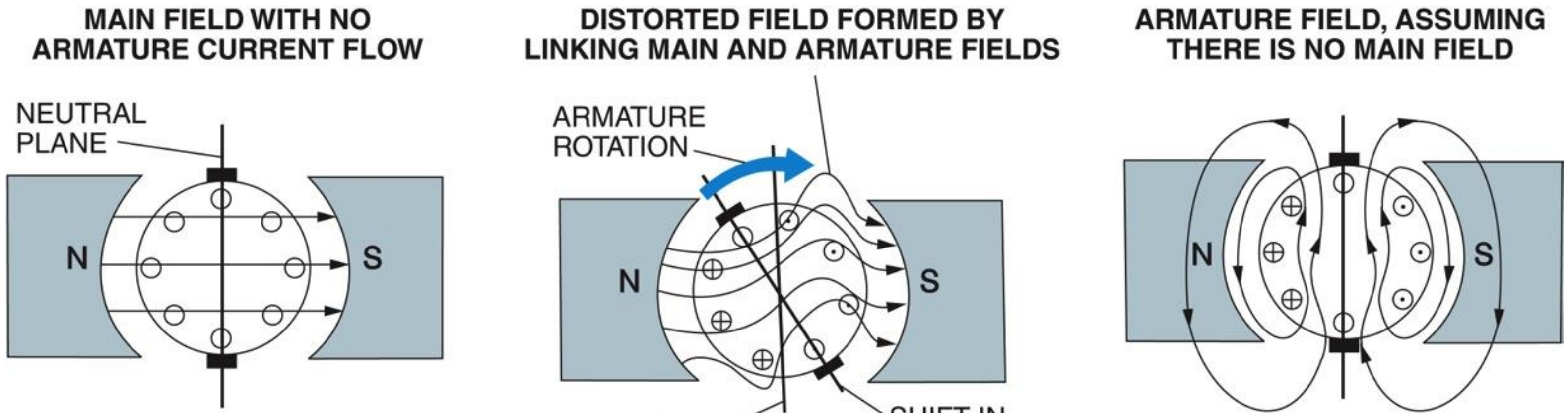
Two-Loop DC Motors

- When an armature contains two loops at right angles, one loop is in the neutral plane while the other is in a position of maximum torque.
- This type of motor is self-starting and operates less erratically than a single-loop motor.



Armature Reaction

- Armature reaction is caused by the interaction of the magnetic fields from the field magnets and the armature.
- The resultant field shifts the neutral plane of the motor.



There are two magnetic fields in the gap between the pole pieces of the electric motor. One is the main magnetic field. The second is the magnetic field of the armature.

Combining the two fields results in a distorted main field whose perpendicular neutral plane is shifted backward against the direction of rotation.

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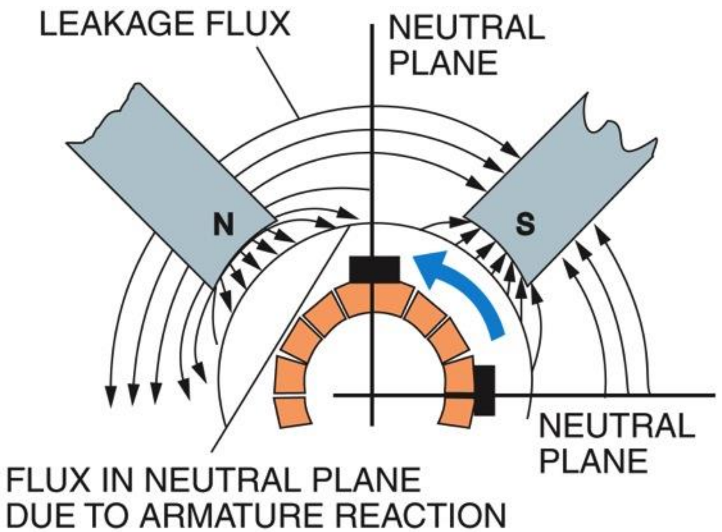
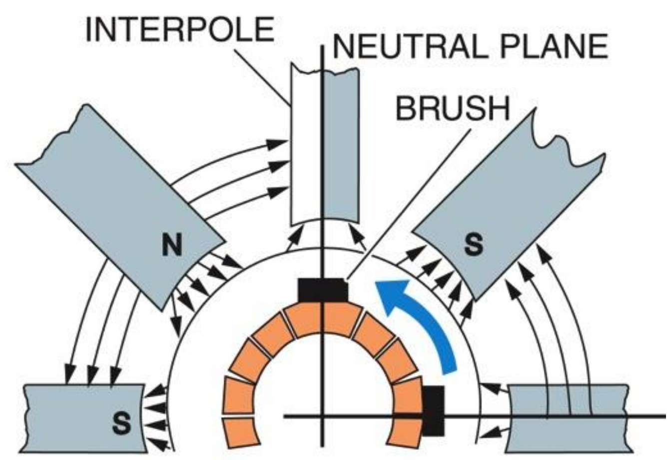
Interpoles

Armature reaction can be overcome by installing interpole windings.



Interpoles produce a local field at the neutral plane that opposes the flux produced by armature reaction to restore the original neutral plane.



Interpoles are used on practical DC motors to counteract armature reaction.

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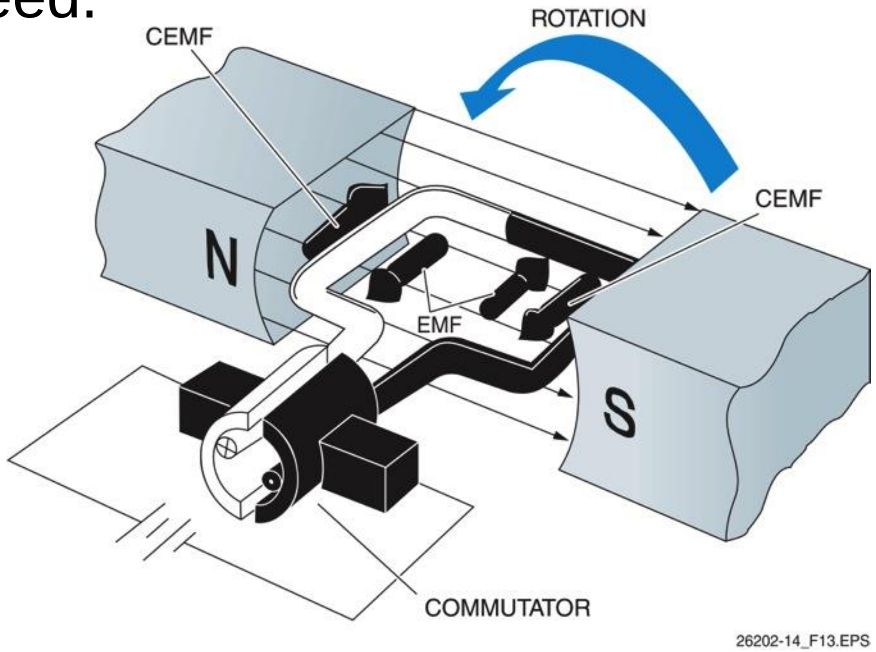
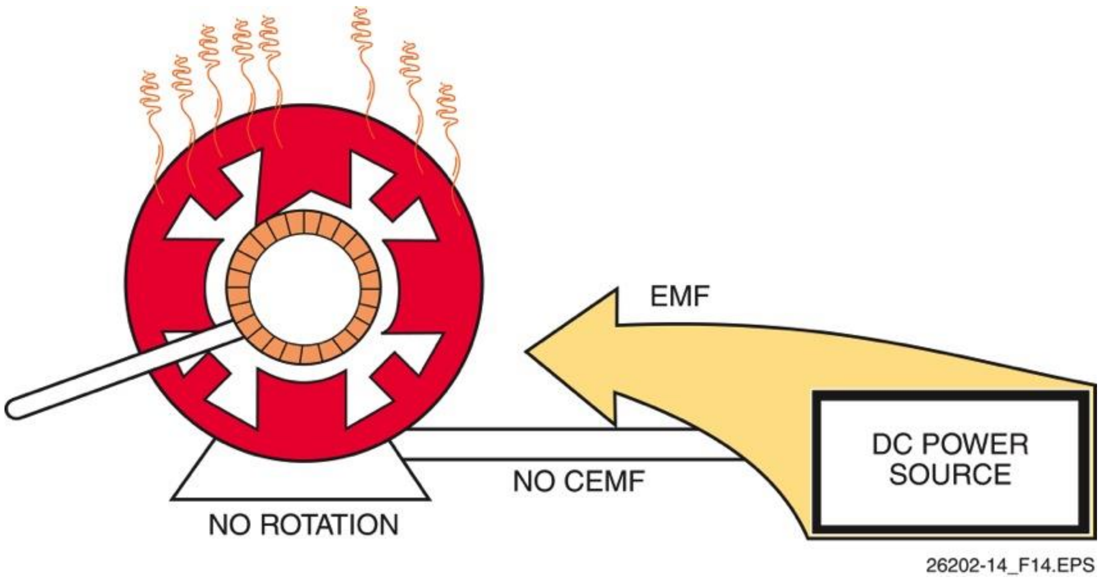
Counter-Electromotive Force (CEMF)

- Counter-electromotive force (CEMF) is generated by the action of the armature windings cutting the lines of force of the field poles.
- The value of CEMF depends on the field strength and the armature speed.



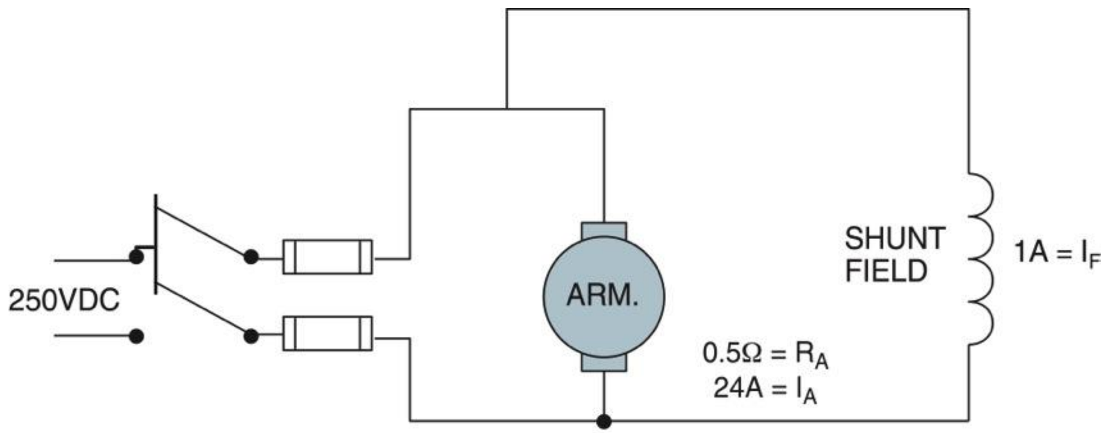
No CEMF

- CEMF is necessary for proper motor operation and reduces the armature current to a low enough level to drive the motor without excessive heating.
- If the armature stalls and no CEMF is produced, the motor draws too much current and becomes overheated.



Starting Resistance

- Large DC motors require the addition of a starting resistance to limit the current until CEMF is produced by the motor operation.
- A starting resistance typically limits the current to 1.5 times the full-load amps (FLA).
- After starting, the resistance is removed from the circuit.



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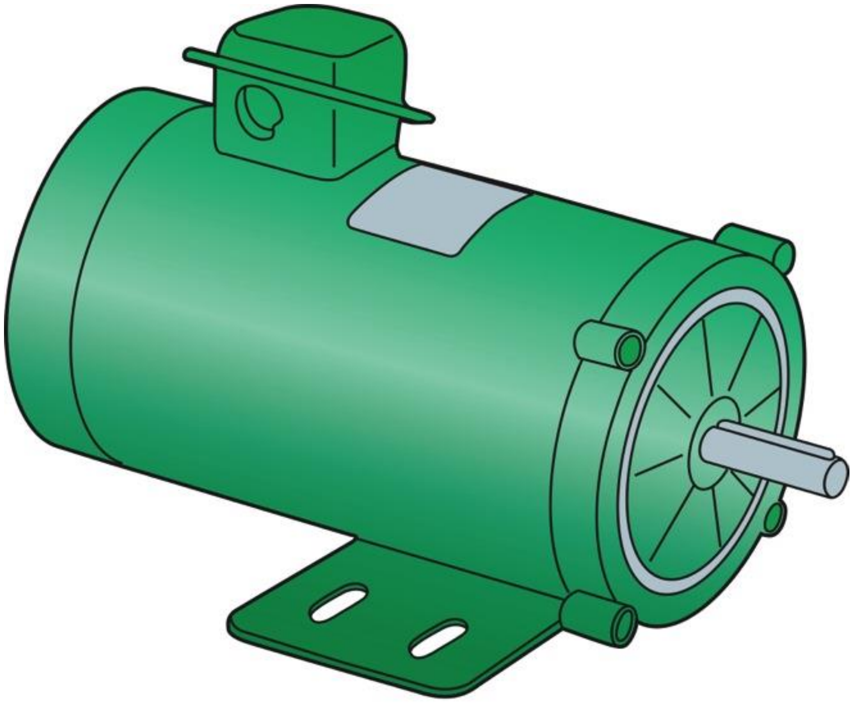
Types of DC Motors

- A series motor has the field coils connected in series with the armature (rotor) winding.
- A shunt motor has the field coils connected in parallel with the armature (rotor) winding.
- A compound motor has both a series- and a shunt-connected field.



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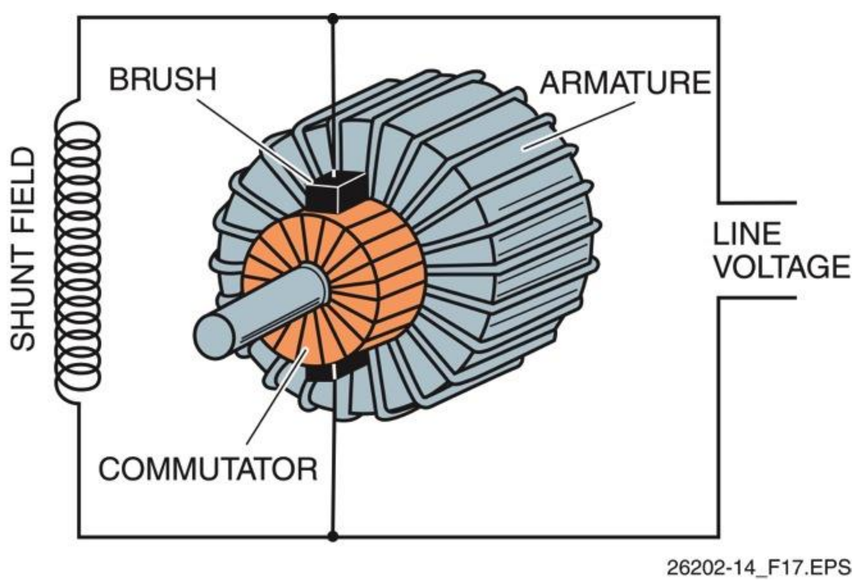
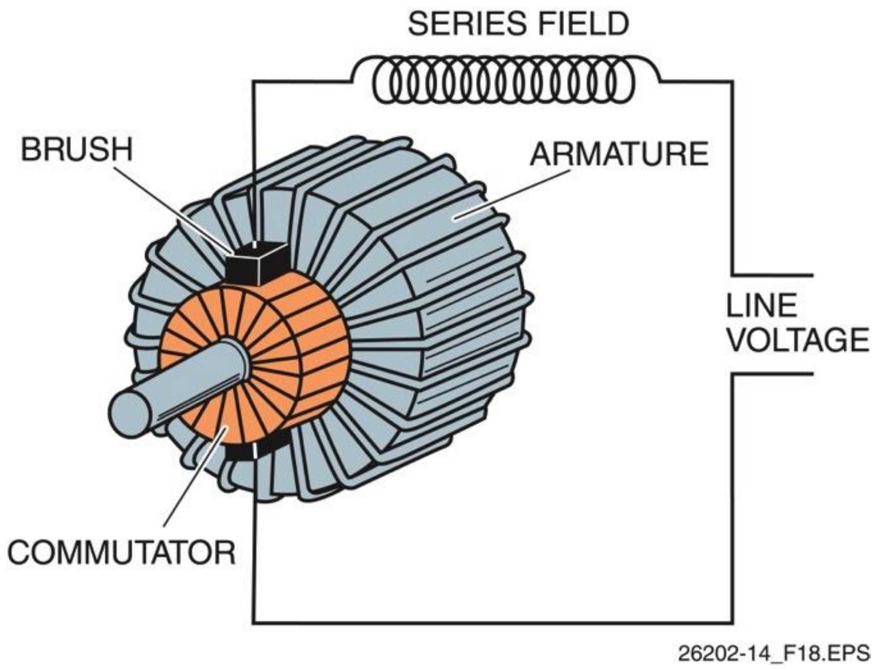
Shunt Motors

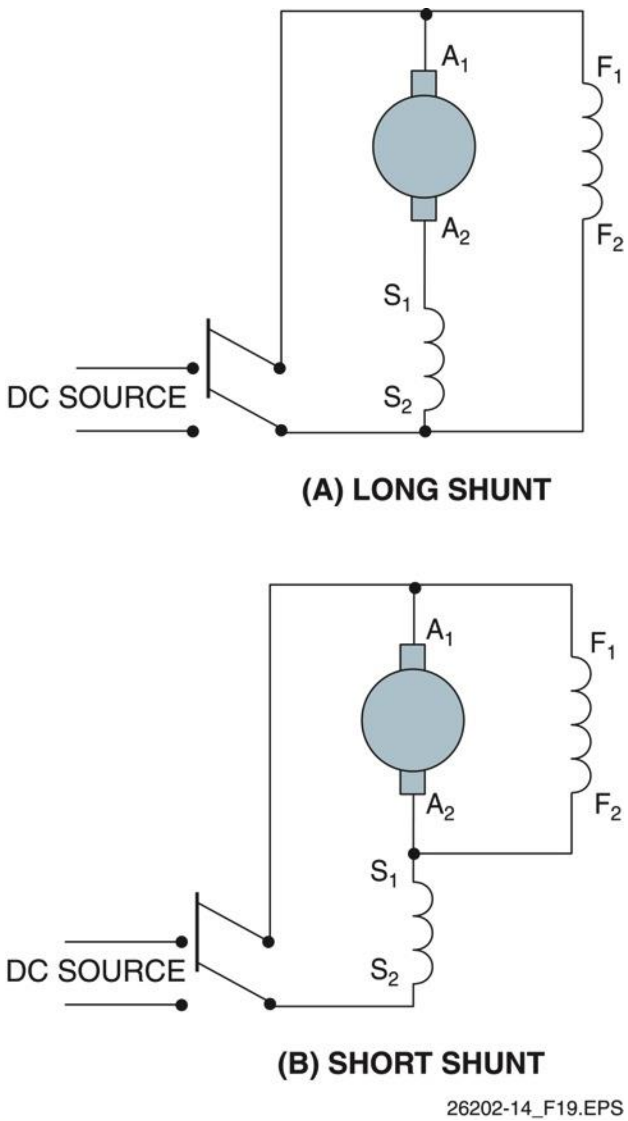
- The current through a DC shunt motor varies depending on the load (the larger the load, the larger the current, and vice versa), and this results in minor speed changes.
- Shunt motors have excellent speed control.
- Shunt motors do not develop as much starting torque as series motors and are generally used with smaller loads.



Series Motors

- DC series motors are used in applications requiring large amounts of starting torque, such as cranes.
- The speed control of a series motor can be improved with the addition of a motor controller.

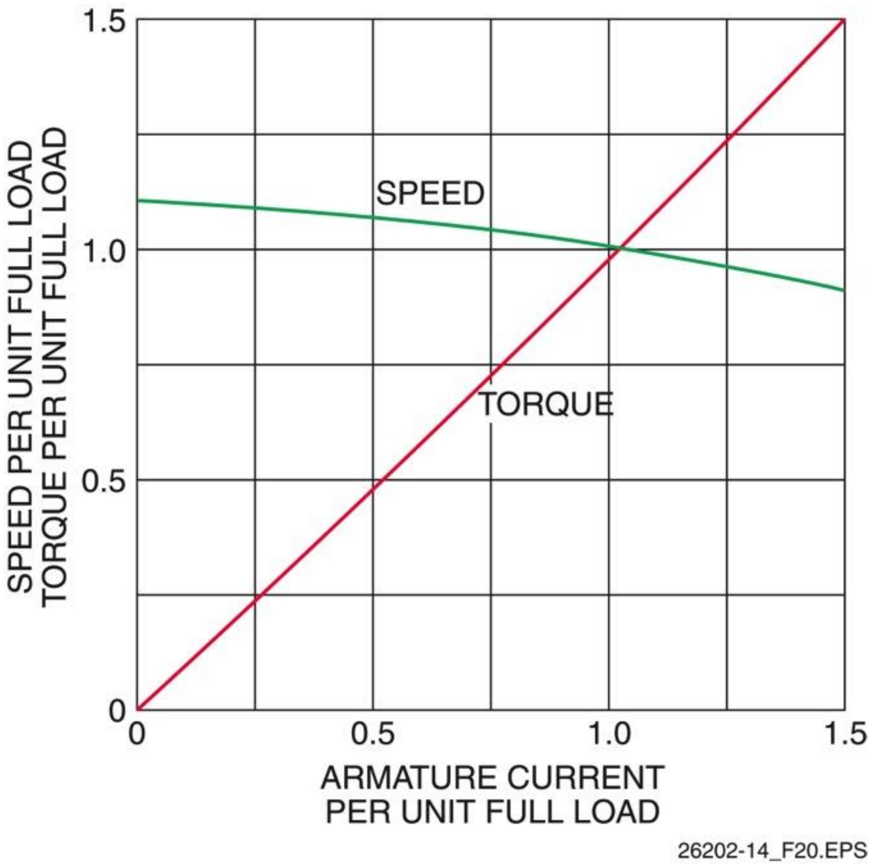




Compound Motors

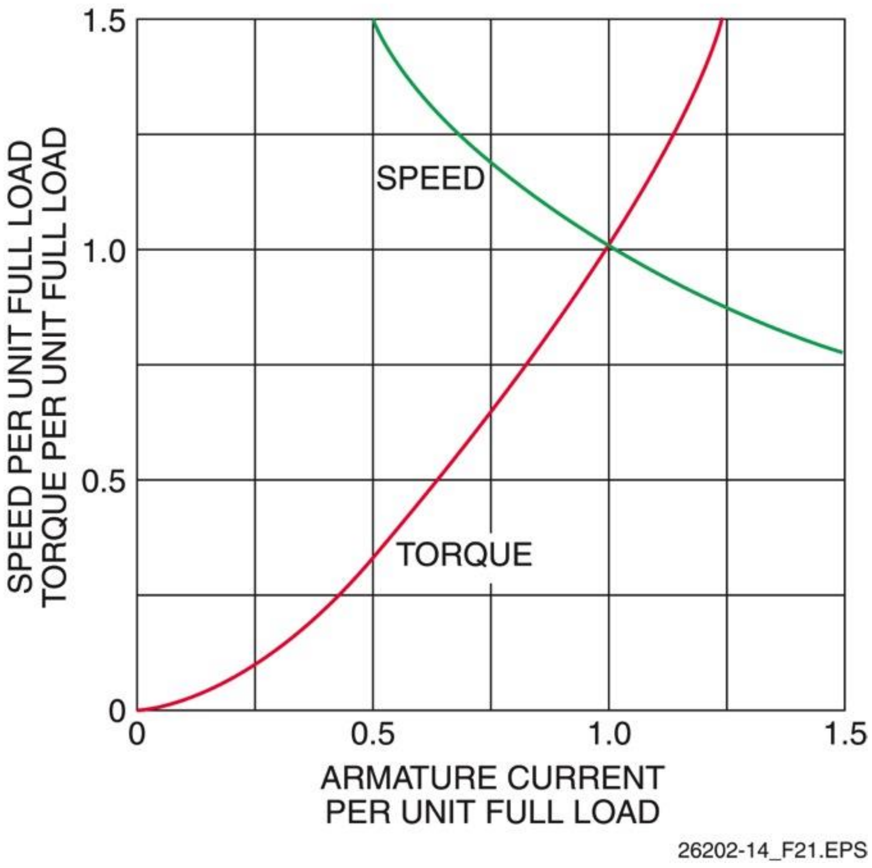
- DC compound motors are used to provide both high starting torque and constant speed under load.
- Compound motors contain a shunt and a series winding on each field pole.

Operating Characteristics of a Typical DC Shunt Motor



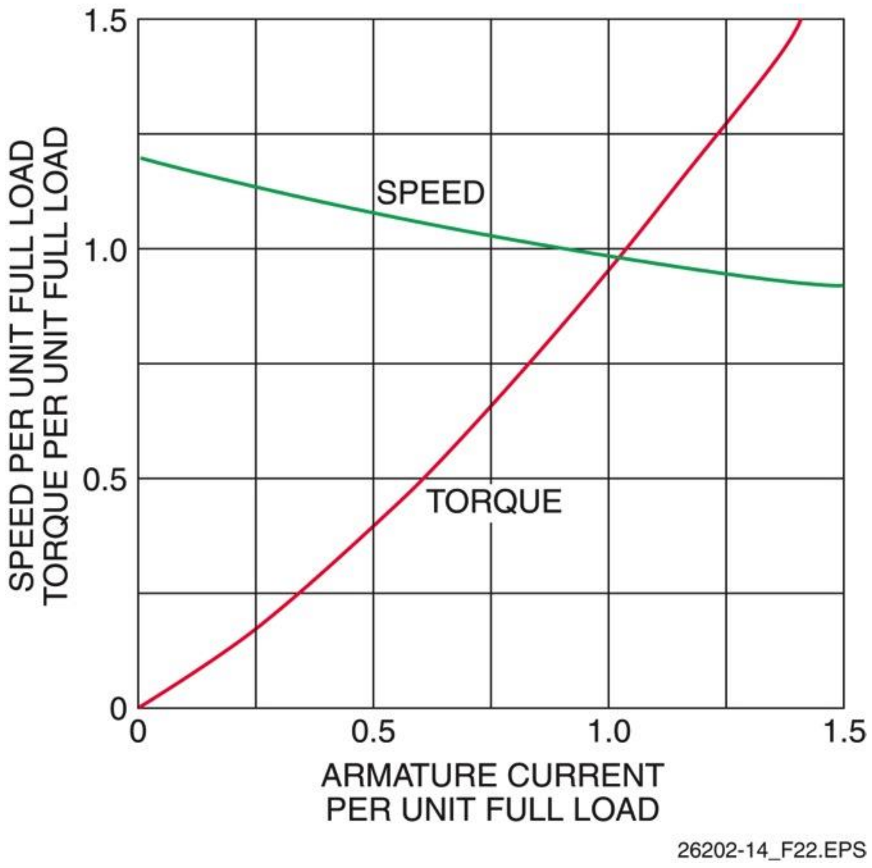
Note that the speed of a DC shunt motor is fairly consistent up to 150% of the rated capacity.

Operating Characteristics of a Typical Series Motor



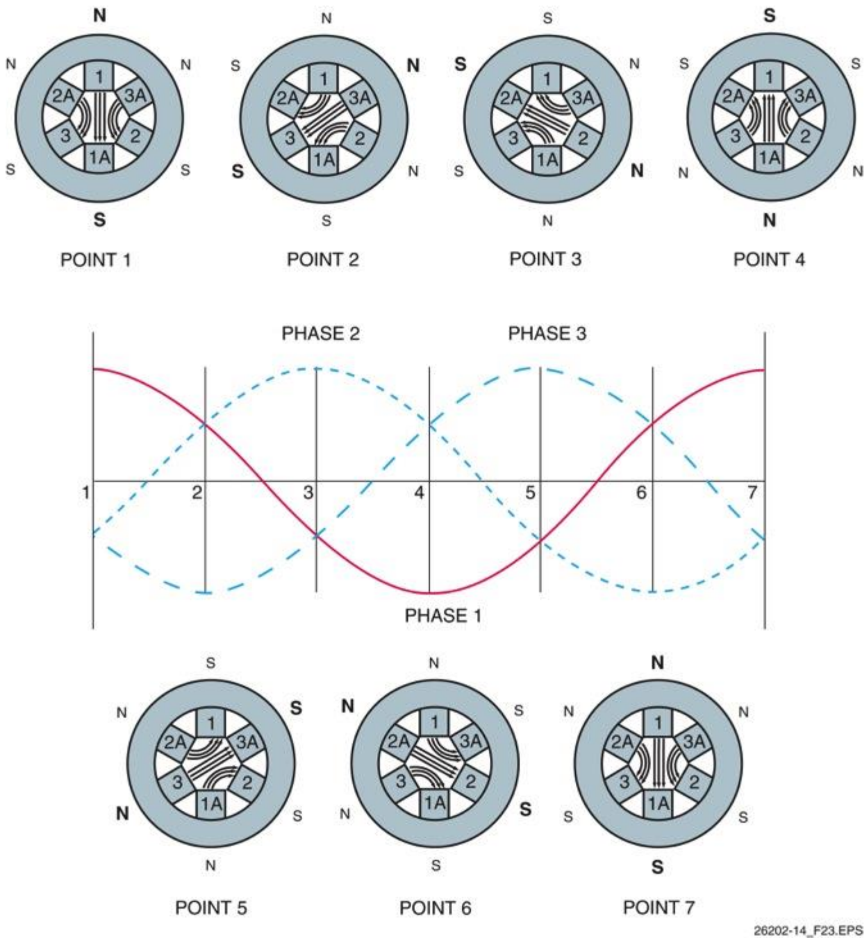
Note that the speed of a series DC motor varies greatly with the applied load.

Operating Characteristics of a Typical DC Compound Motor



A compound DC motor provides better starting torque than a shunt motor and better speed control than a series motor.

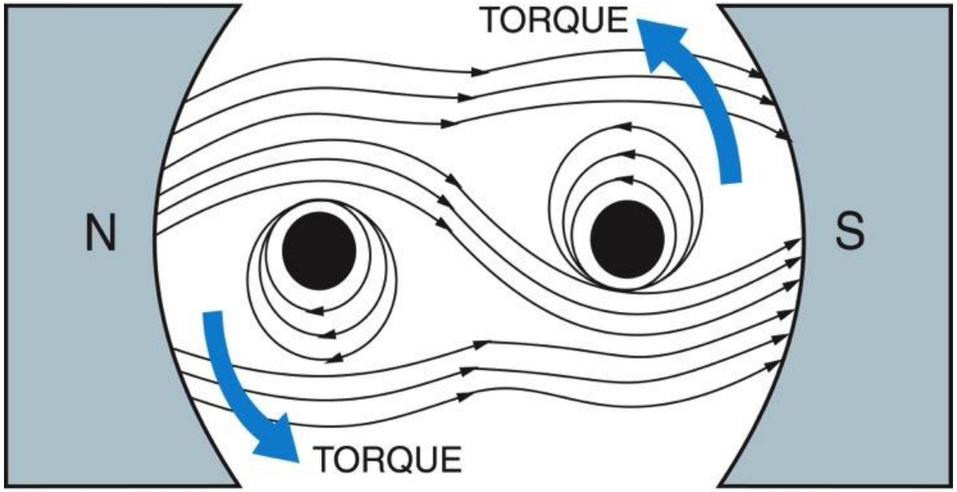
Alternating Current Motors



- Single-phase motors are typically limited to fractional-horsepower applications, such as fans, appliances, and other low-load devices.
- Polyphase motors are used to drive large machinery such as pumps and compressors. The stator windings are set up to create rotating magnetic fields that act on the rotor to operate the motor.

Three-Phase Induction Motors

- In induction motors, the rotor currents are supplied by electromagnetic induction. The stator windings connect to three-phase power to produce a rotating magnetic field.
- There are two main types of three-phase induction motors: the squirrel cage motor and the wound rotor motor.



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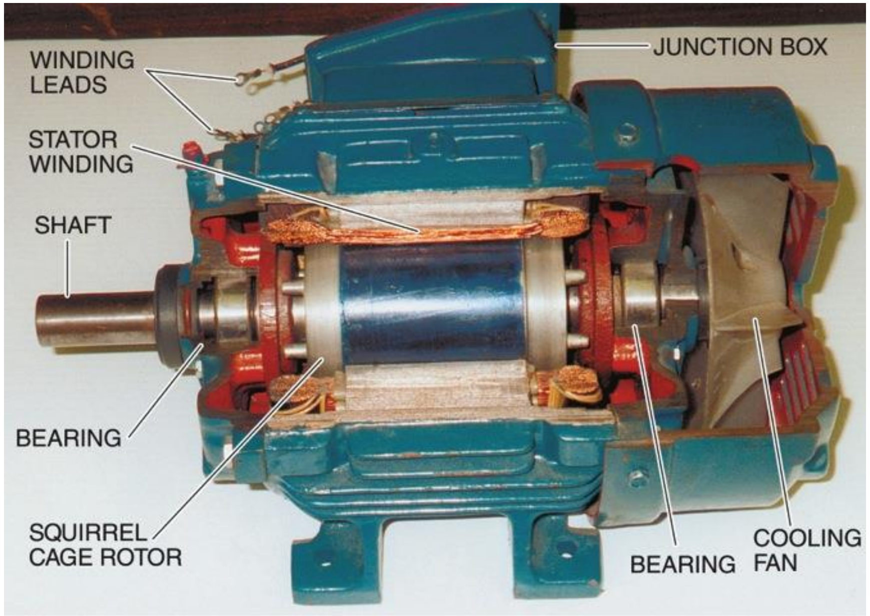
Squirrel Cage Induction Motor

- The squirrel cage is the most popular rotor in use.
- Because they operate on induction, squirrel cage rotors have no brushes or slip rings, and consist of a stator and a rotor in a cast frame with bearings on either end.



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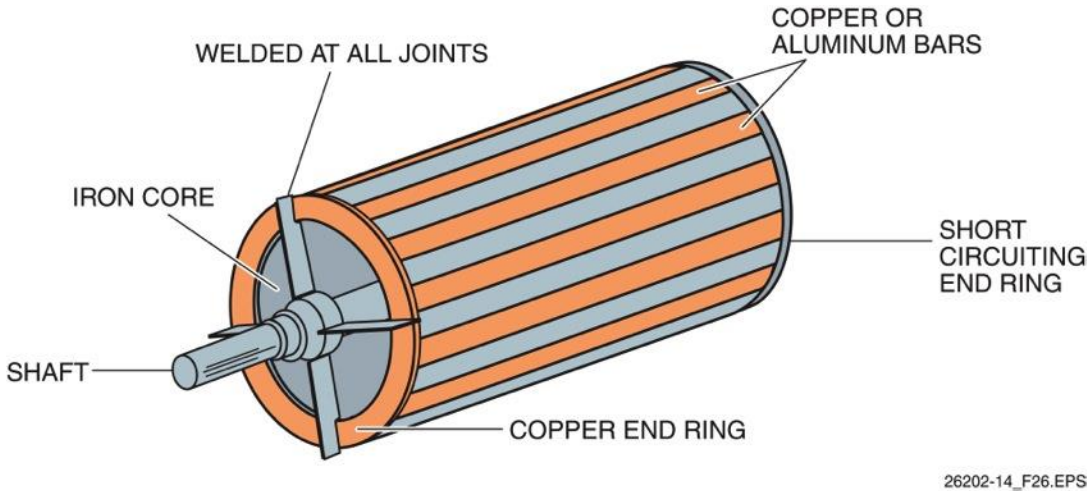
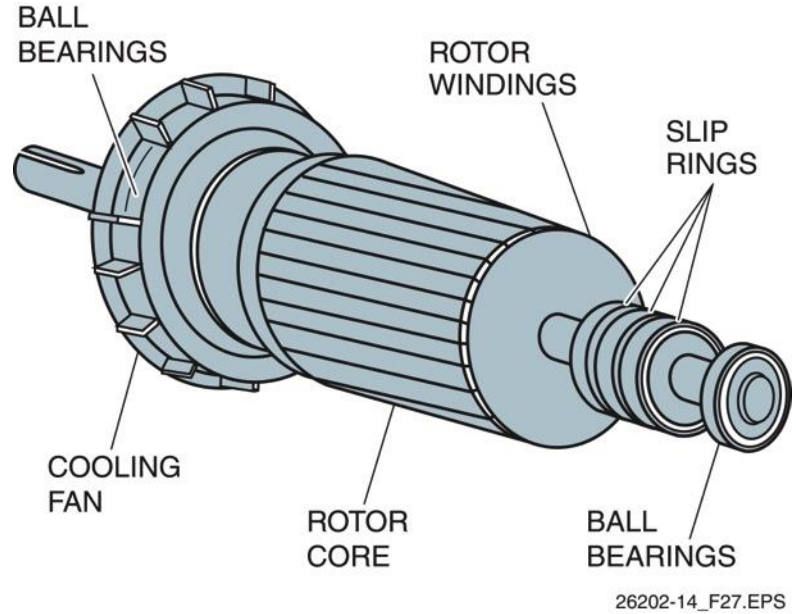
Squirrel Cage Rotor

- A standard squirrel cage motor is used to drive loads that require variable torque at a consistent speed with high full-load efficiency.
- If a load requires extra torque when starting, a squirrel cage rotor can include both starting and running configurations. This is known as a double squirrel cage rotor.



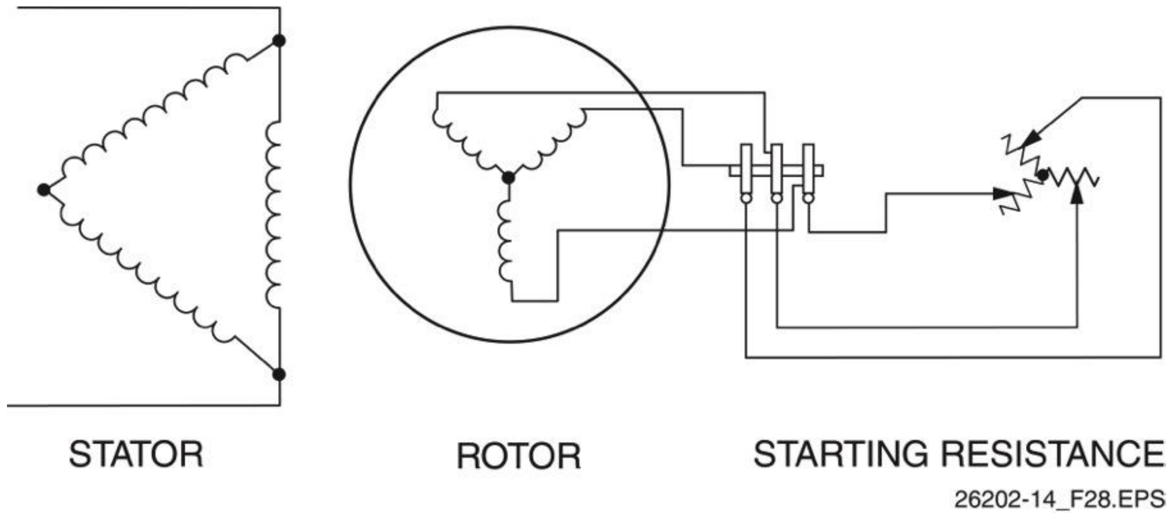
Wound Rotor Induction Motor

- Wound rotor windings are usually connected to slip rings mounted on the rotor shaft. They are used with brushes to provide an electromechanical connection to the rotor.
- A variable resistor can be used to limit the resistance when starting. Wound rotor motors are often used for applications that require frequent starts without overheating the motor.

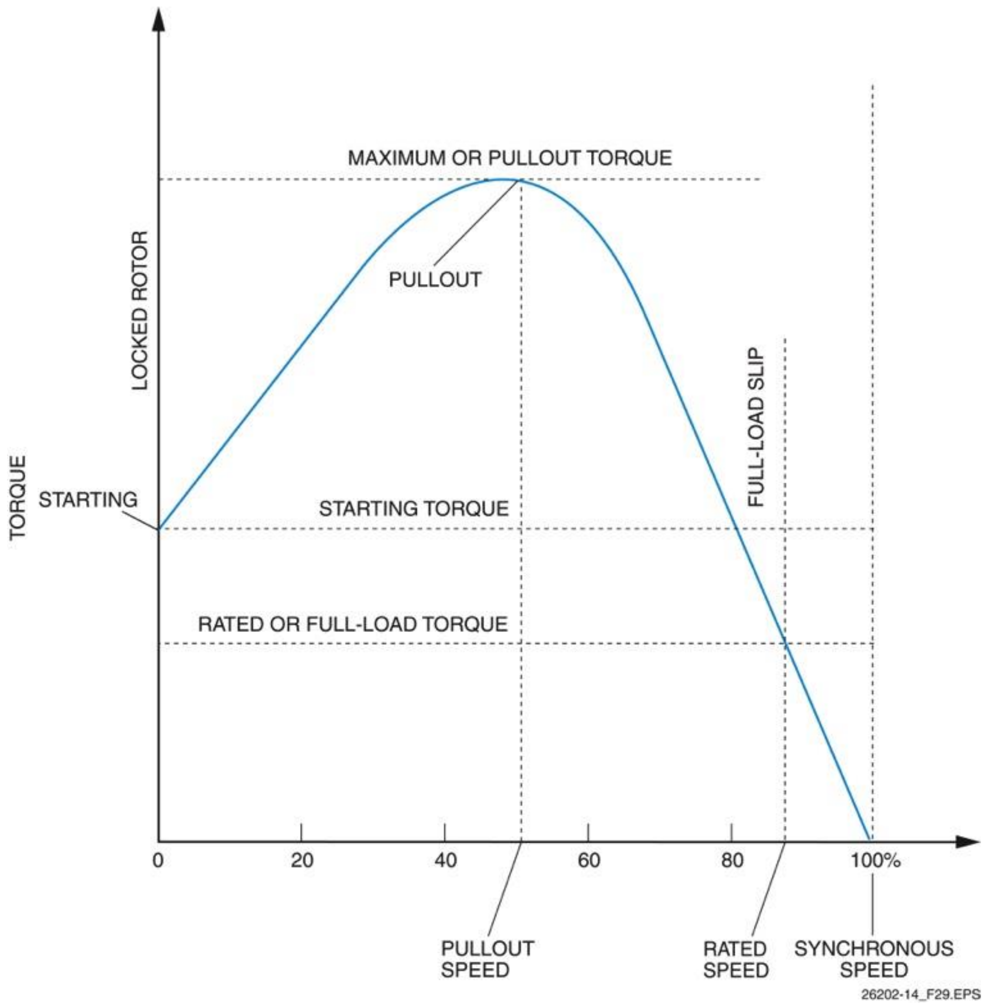


Wound Rotor Motor Circuit

- A resistance can also be used to provide adjustable speed control.
- Wound rotor motors provide good running characteristics but have higher maintenance requirements than squirrel cage motors.



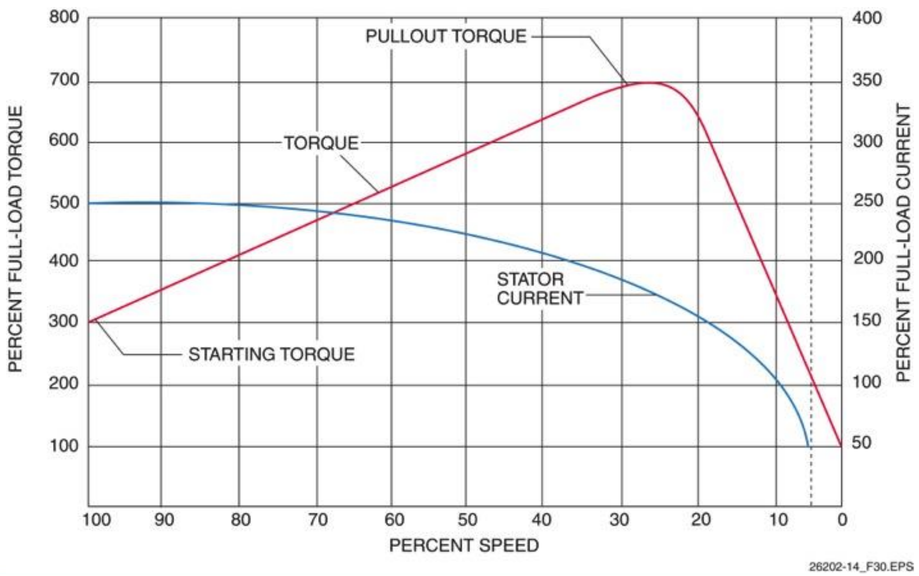
Typical Torque-Speed Curve



- In an induction motor, the rotor always operates at less than synchronous (full) speed due to the mechanical load and friction. This is known as slip.
- The full-load slip may reduce the speed of the motor by up to 10%.

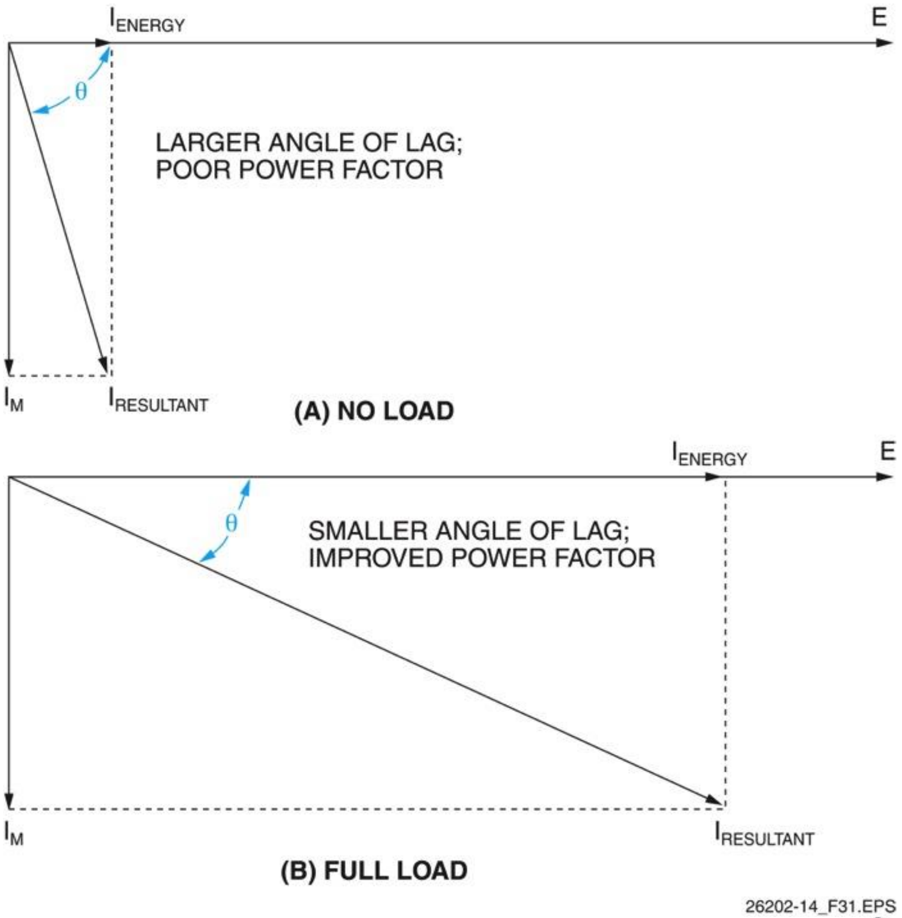
Overload Condition

- The motor torque climbs after starting until it reaches its full-rated load and then continues to climb until it reaches the pullout torque.
- If pushed beyond the pullout torque, the motor will stall. An example of this is when a circular saw stalls during cutting.



Power Factor and Speed Control

- The power factor of a squirrel cage induction motor is best at high-load conditions and worst at no-/low-load conditions.
- Squirrel cage motors are either used in constant-speed applications or where speed control can be provided by means of variable frequency drives.



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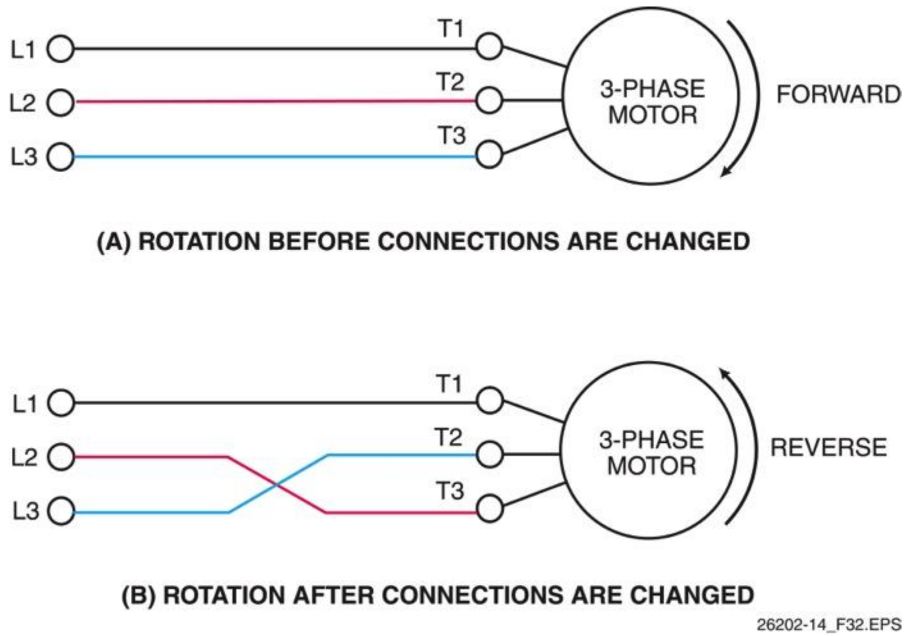
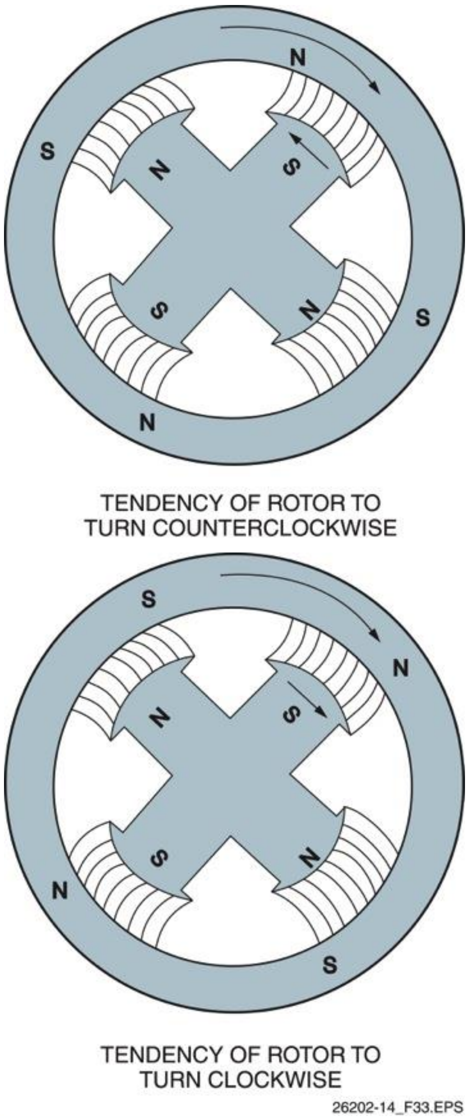
Reversing Rotation

- The direction of rotation of a three-phase induction motor can be changed by reversing two of the three incoming leads.
- Always connect leads carefully to endure proper rotation.



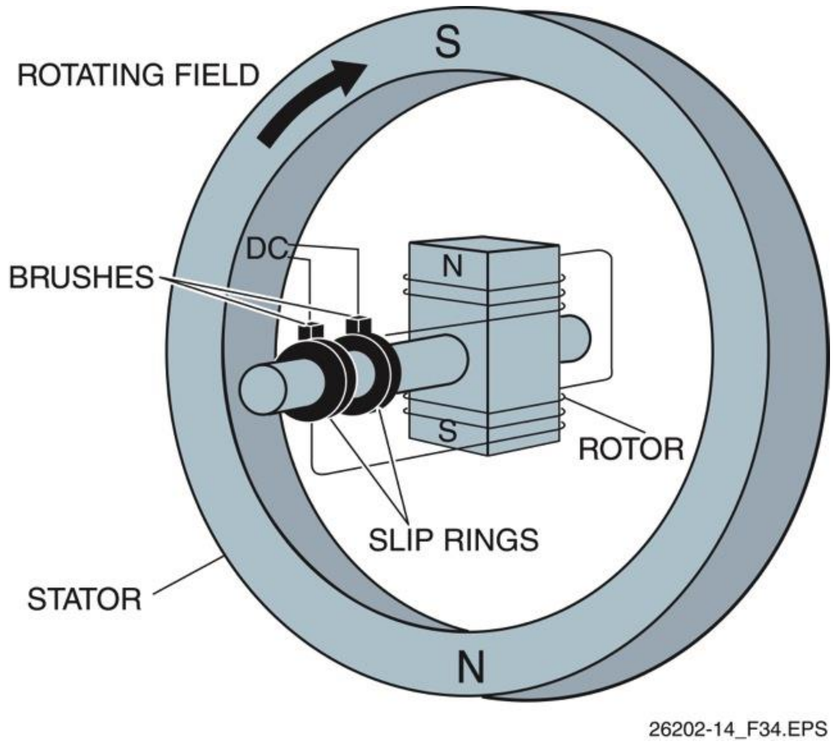


Synchronous Motors

- A synchronous motor operates at synchronous speed from no-load to full-load conditions and can be used to correct a low power factor.
- The rotor is energized by a DC source separate from the three-phase AC that powers the stator windings.
- An amortisseur winding is used to overcome the lack of starting torque.

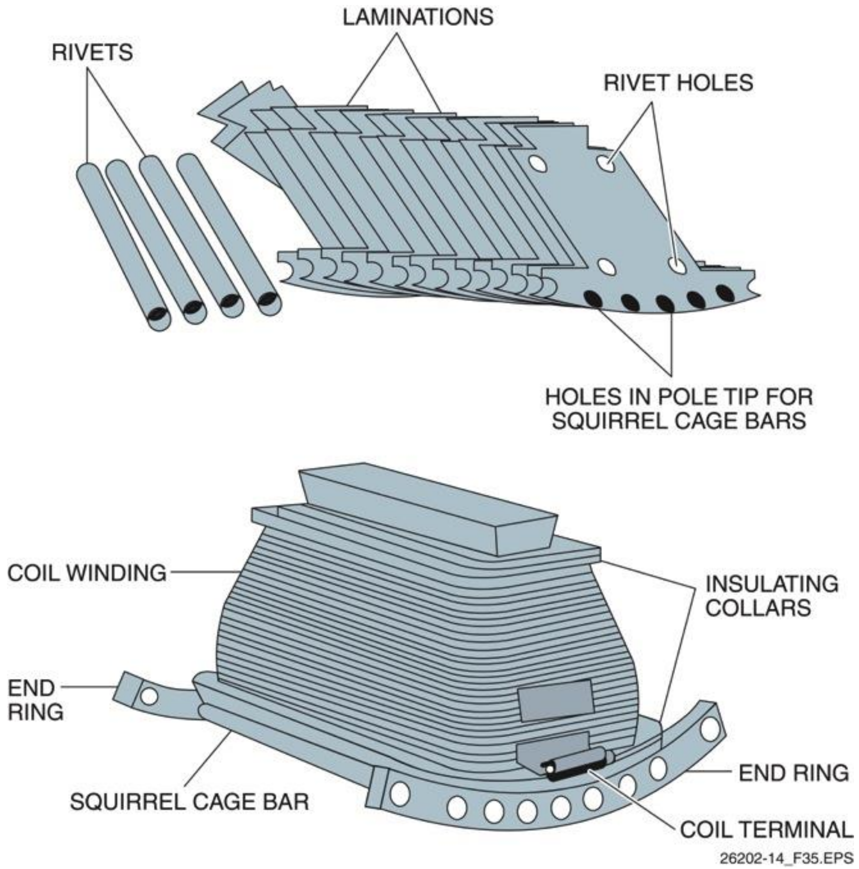
Simplification of a Synchronous Motor

The rotor windings are constructed so that the north and south poles will lock in with the revolving field produced by the DC motor.



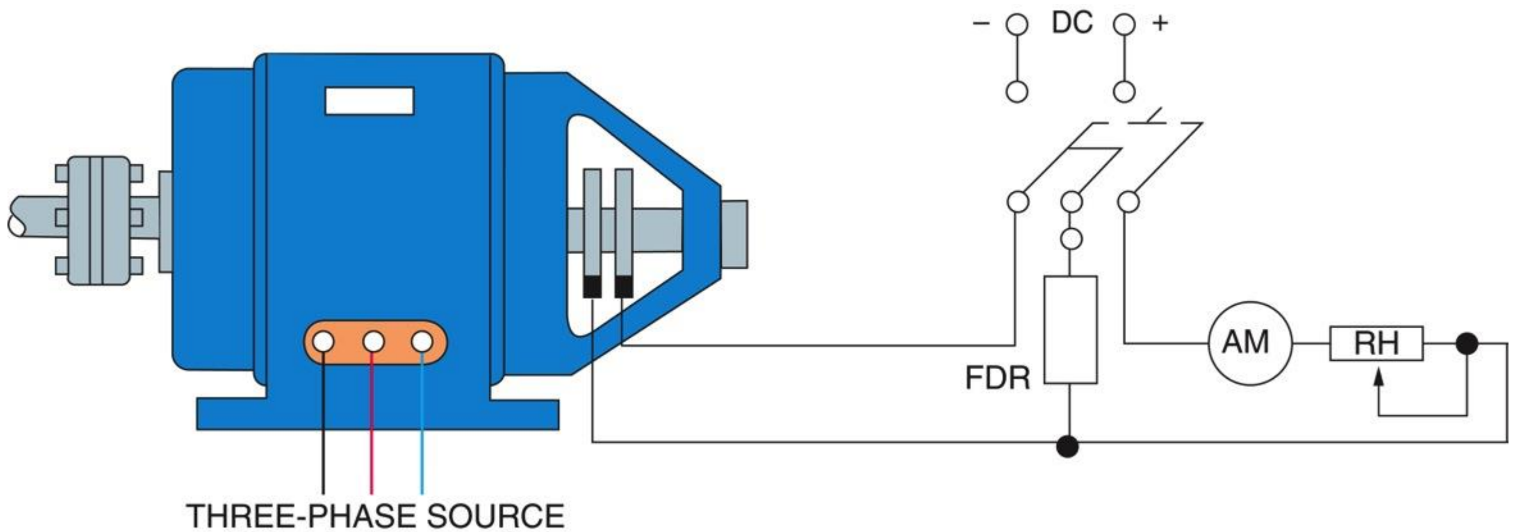
Pole Assembly

- The rotor field windings connect to slip rings on the rotor shaft and the field current is supplied through brushes to the field windings.
- When a synchronous motor is started, current is applied to the stator windings and induced in the amortisseur windings.



Rotor Field Excitation

- The rotor must be excited from an external DC source.
- As the DC field strength is increased, the power factor can approach unity or 100%.



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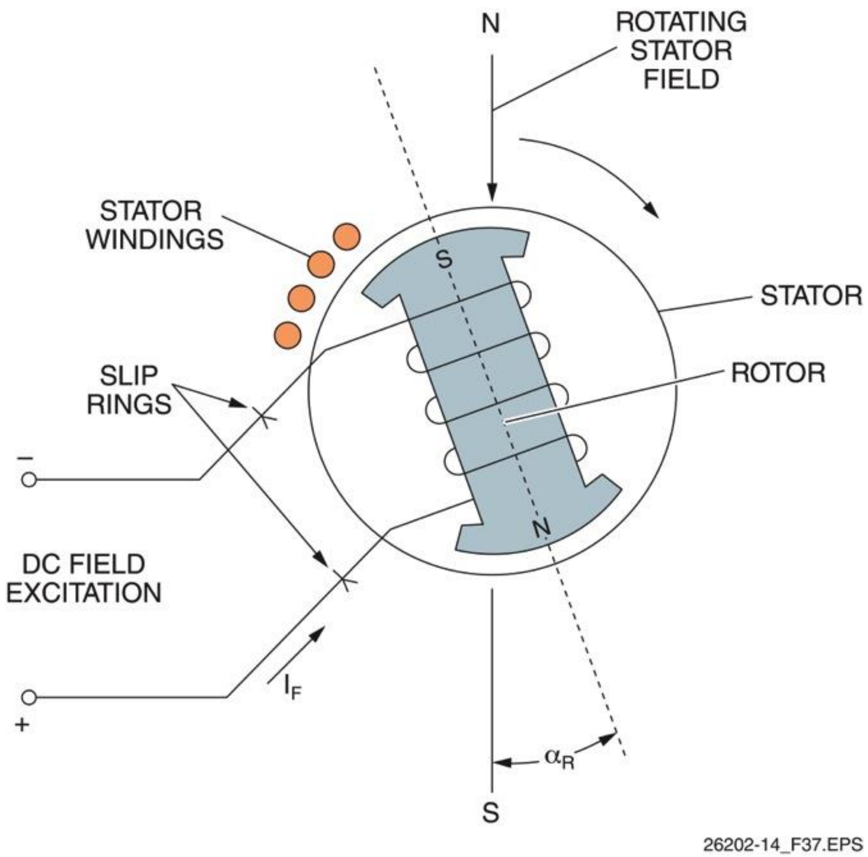
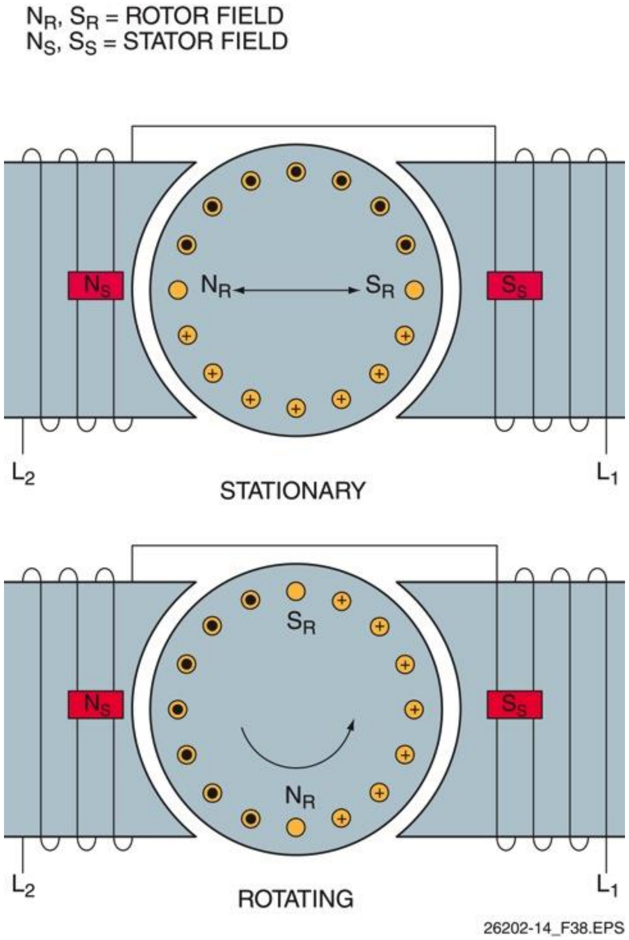
Synchronous Motor Pullout and Torque Angle

- Conditions that may cause a motor to lose synchronism (go out of step) include excessive loads, reduced supply voltage, and lost/low motor excitation.
- While the motor is running, the two rotating fields will align and the rotor pole will lag the stator pole by a predetermined angle known as the torque angle.



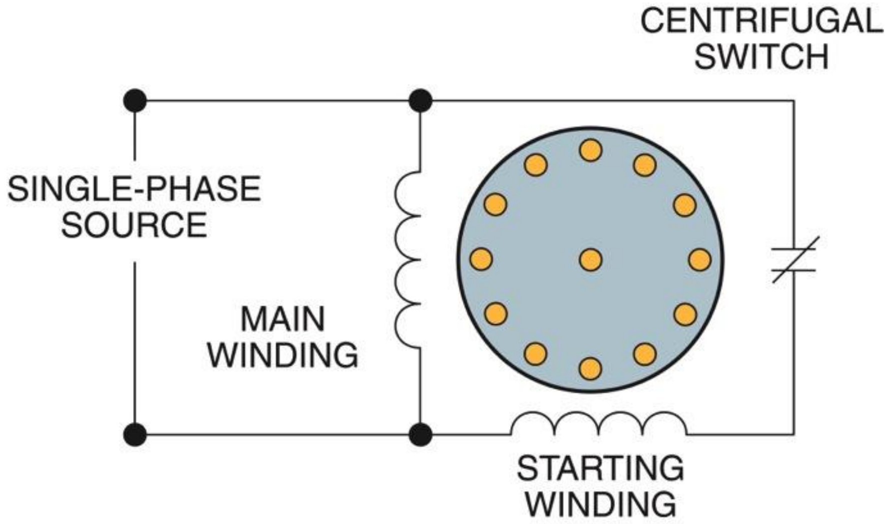
Single-Phase AC Motors

- Single-phase AC motors are commonly used in various small and large household appliances.
- A single-phase AC induction motor has a stationary stator that alternates polarity between poles. Voltage is induced in the rotor and an outside force is required to begin rotation (typically a starting circuit).



Split-Phase Induction Motor

- A split-phase motor has both a starting winding and a main (running) winding.
- When the rotor reaches about 75% of rated speed, the starting winding drops out of the circuit and the motor continues to run using the main winding.



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4.4.3

Capacitor-Type Induction Motor

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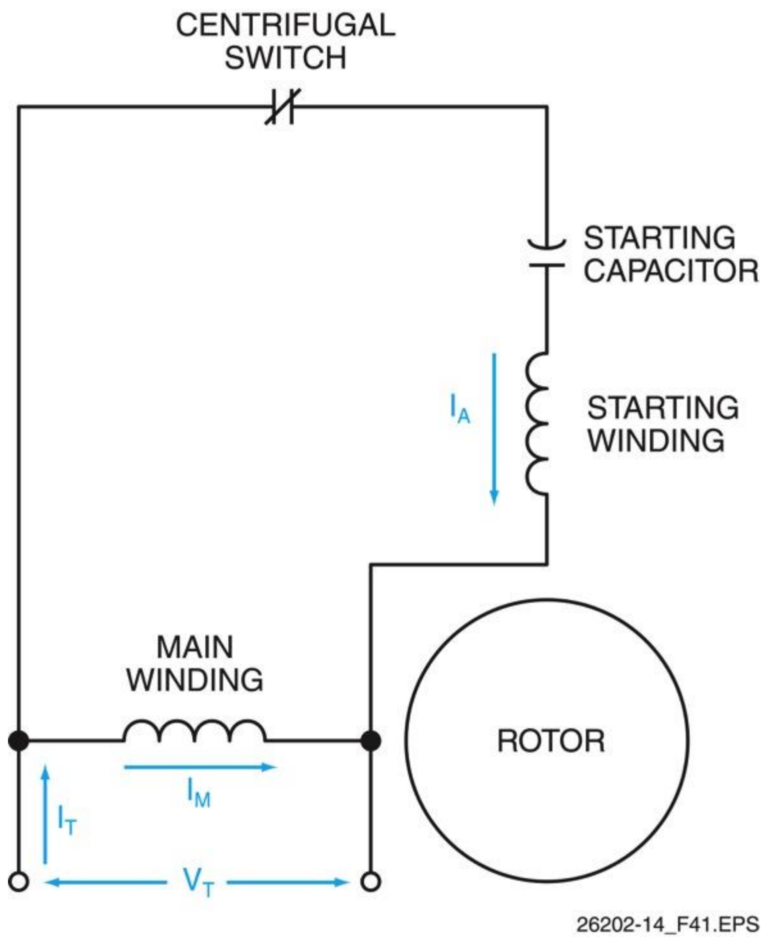
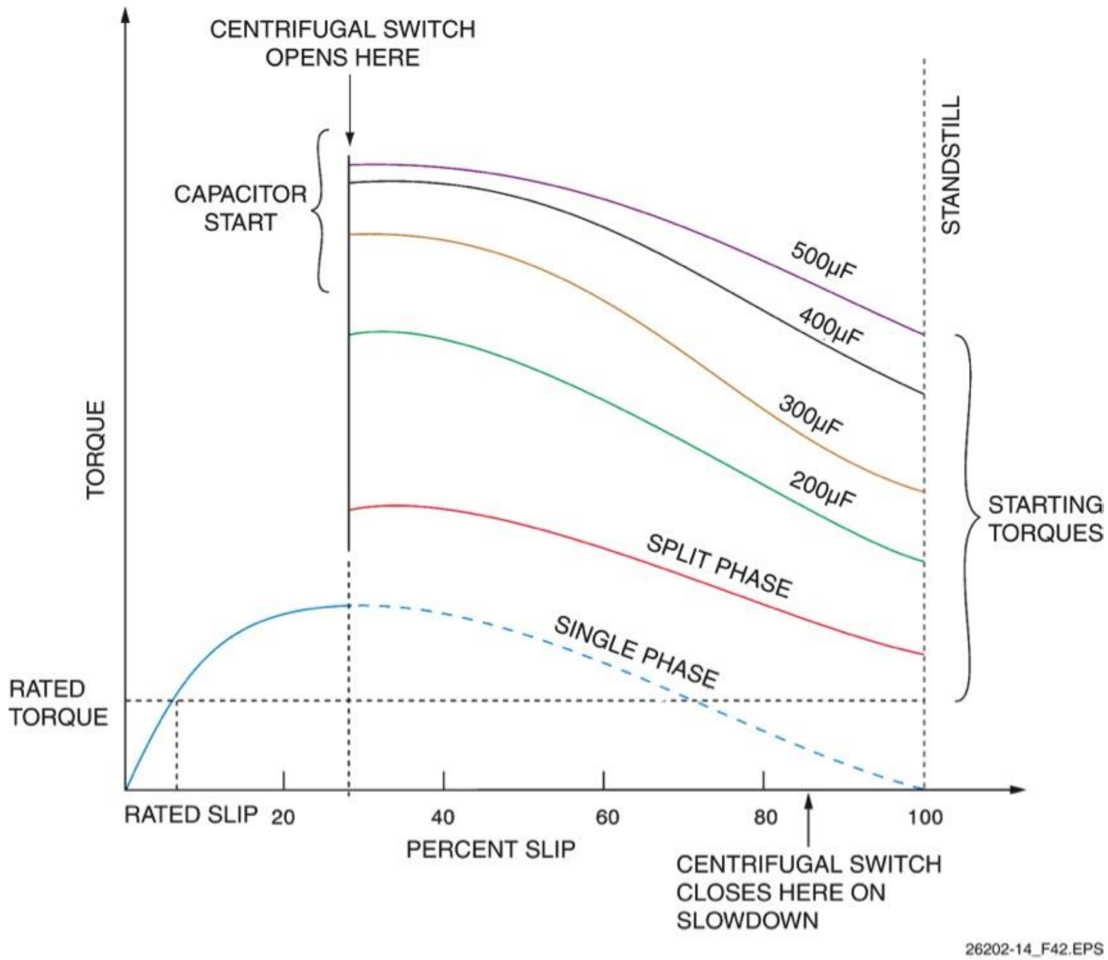
- Capacitor-type motors are similar to split-phase motors but are able to develop a larger starting torque.
- The capacitor is located on top of the motor and provides about four times the rated torque of the motor.

Capacitor-Start Motor Schematic



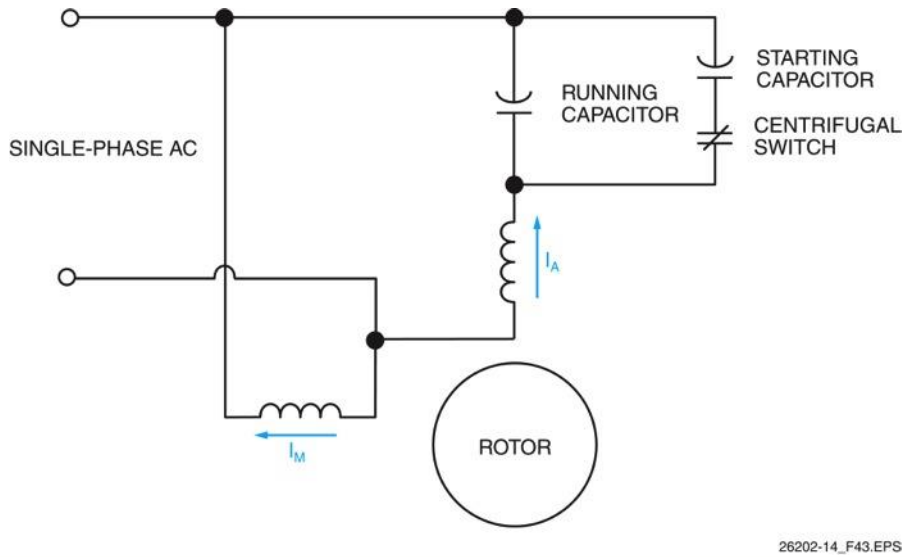
- When a capacitor is placed in series with the starting winding of a single-phase motor, it is called a capacitor-start motor.
- Once the motor is up to speed, the start winding is disconnected and the motor operates in the same way as a split-phase motor.

Torque-Slip Curves



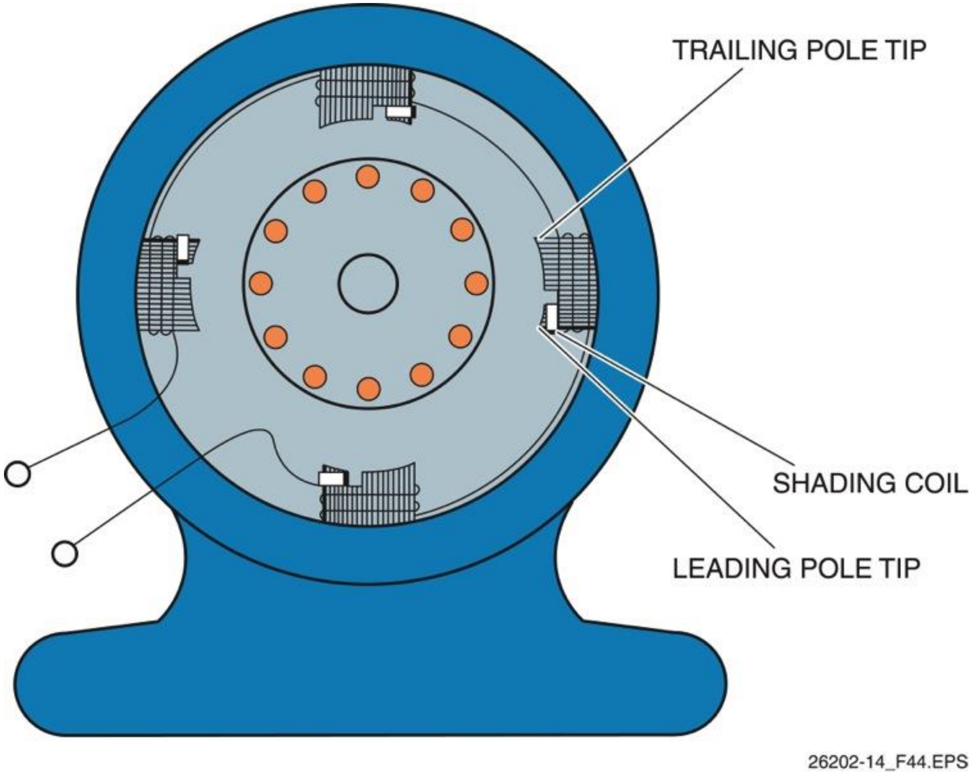
Capacitor-Start, Capacitor-Run Motor Schematic

- A capacitor-run motor leaves the capacitor in the circuit continuously and while it does not provide a high starting torque, it does offer improved running characteristics.
- A capacitor-start, capacitor-run motor uses two capacitors to provide both high starting torque and improved running characteristics.



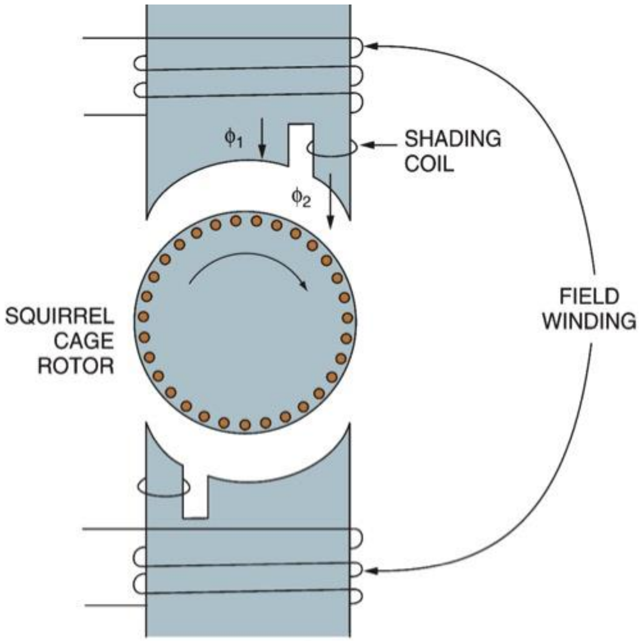
Shaded-Pole Induction Motor

Shaded-pole motors use field coils with copper shading coils to produce a rotating magnetic field.



Two-Pole Shaded-Pole Motor

- Shaded-pole motors are low-horsepower motors used in applications such as small fans.
- They are simple and inexpensive, but provide low starting torque and efficiency, and are noisy during operation.



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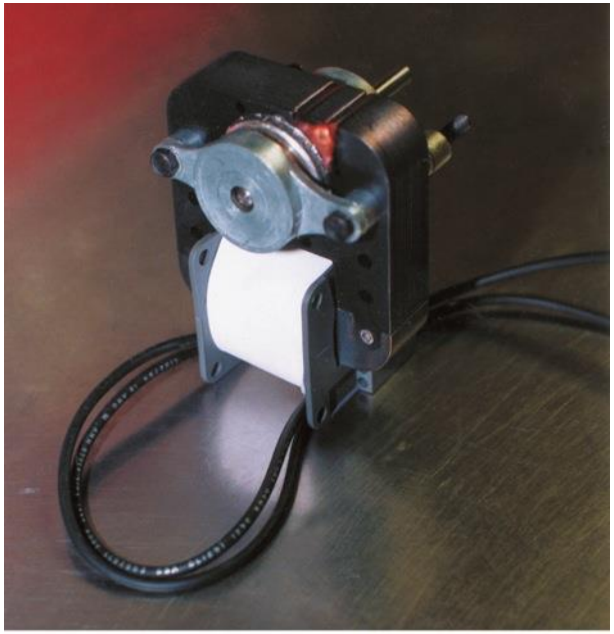

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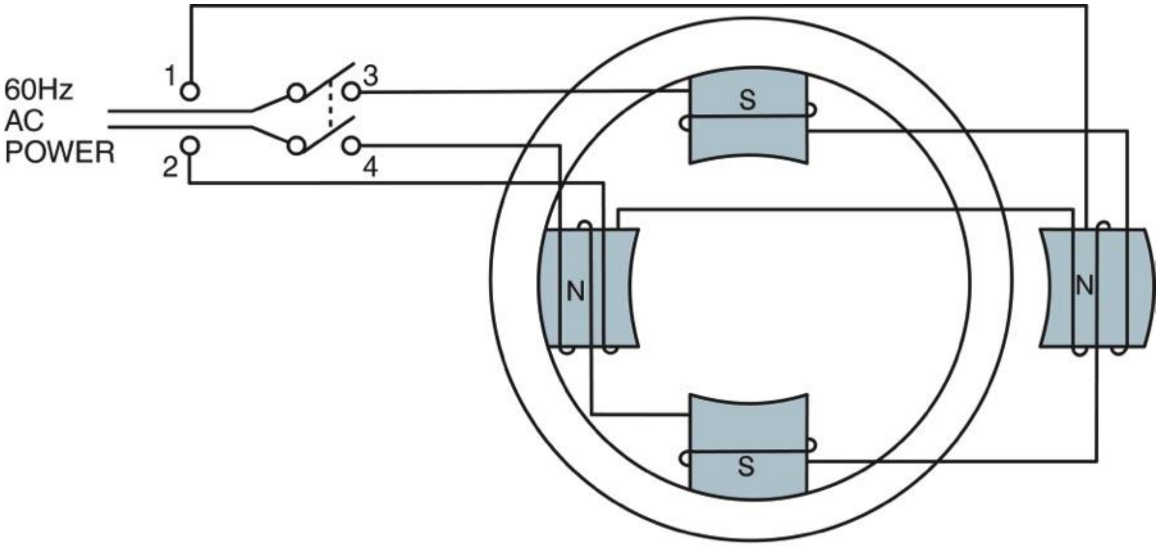
Multiple-Speed Induction Motors

- Motor speed is dependent on the power supply frequency and the number of poles. The speed is normally increased by changing the number of poles.
- Speed control is normally accomplished in a motor controller external to the motor.



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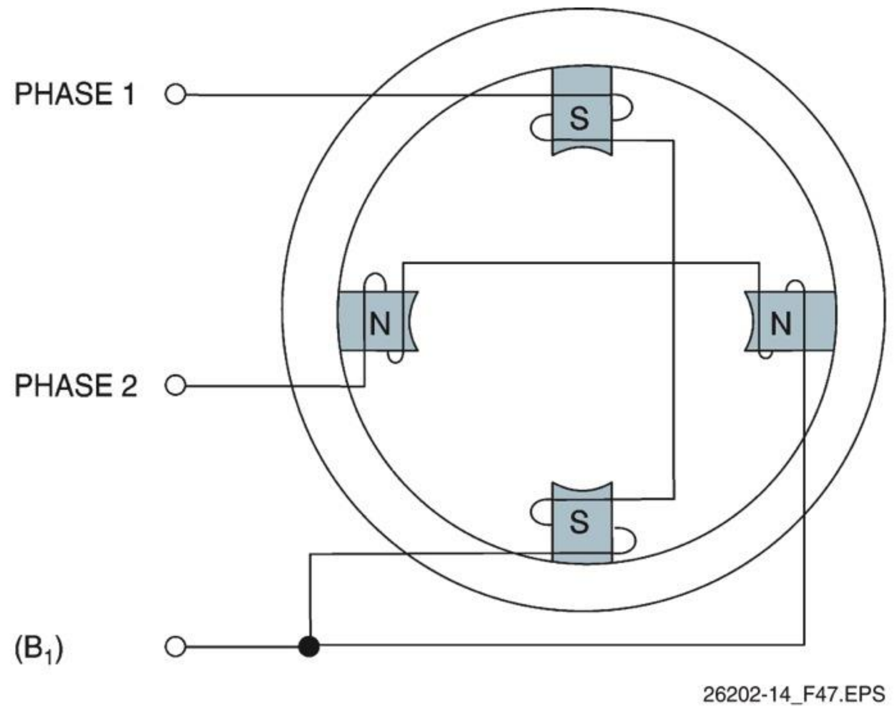
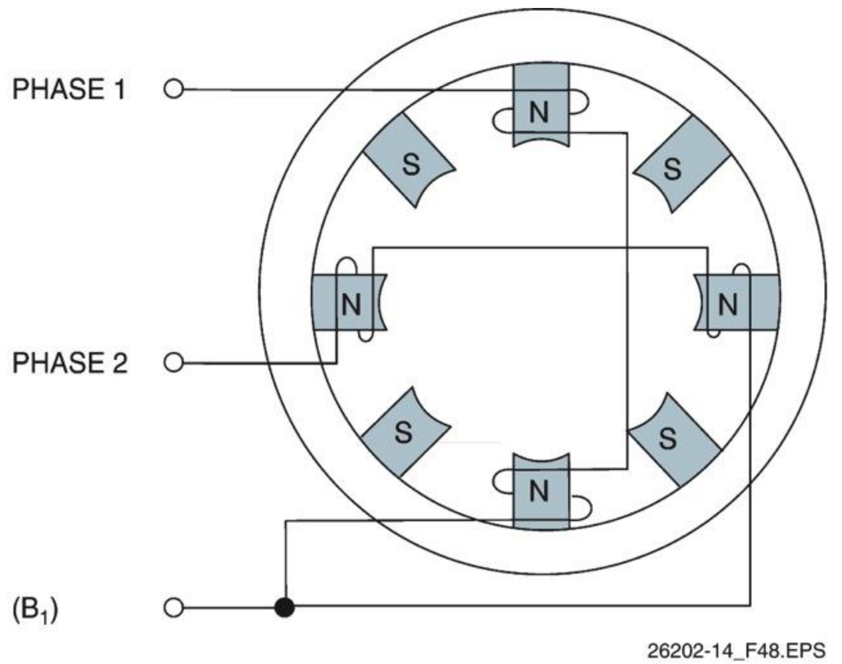
Consequent-Pole Motor

- A consequent-pole motor has two speeds.
- At high speed, two poles per phase are used to provide 3,600 rpm.



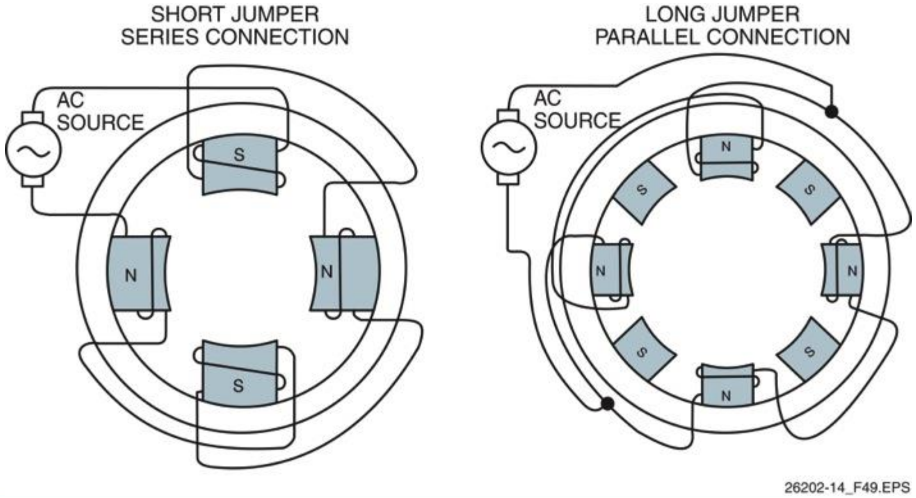
Low-Speed Consequent-Pole Motor

- The connections can be changed to provide four magnetic north poles and consequently, four south poles.
- The four poles per phase produce a rotating magnetic field at 1,800 rpm.



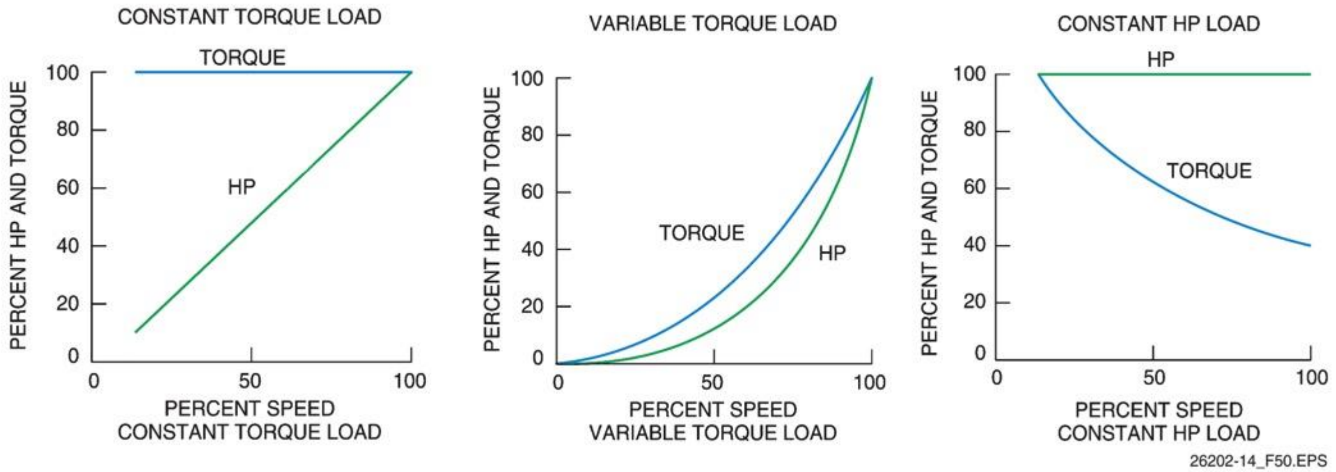
Single-Phase Consequent-Pole Motor

- Parallel connections can be used to create four opposite consequent poles.
- Constant-horsepower motors are used to drive machine tools, while constant-torque motors are used to drive pumps, compressors, and blowers. Variable-torque, variable-horsepower motors are used in fans and air conditioners.



Variable-Speed Drives

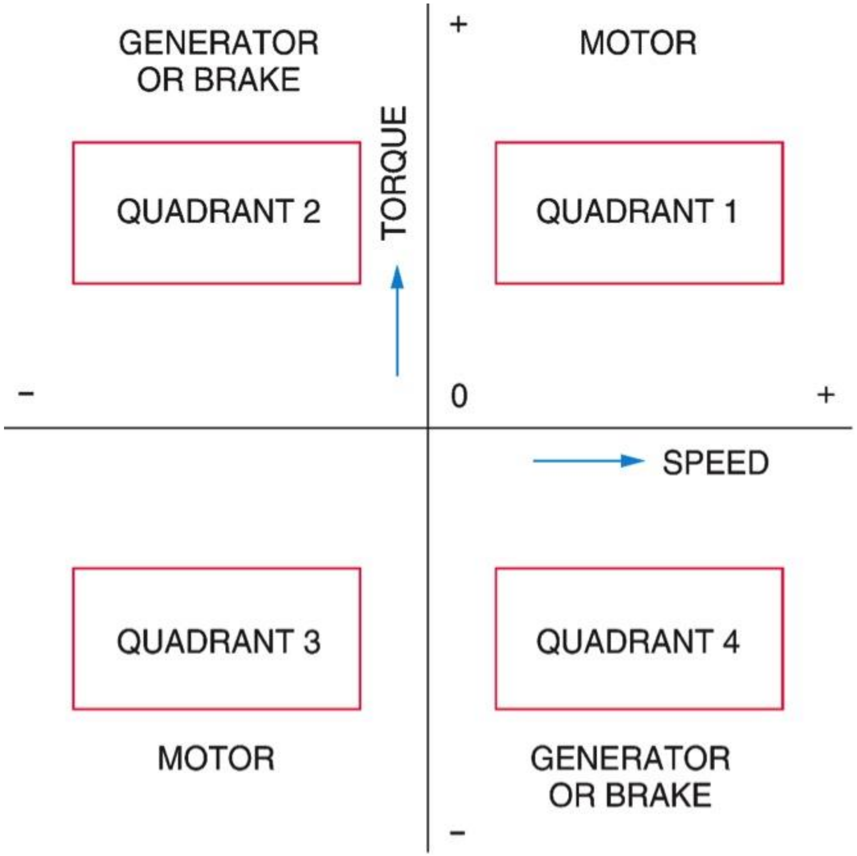
- A constant-torque load requires the same torque regardless of speed, but the horsepower increases with the speed.
- A variable-torque load requires less torque and horsepower at lower speeds.
- A constant-horsepower load requires more torque at lower speeds, but the horsepower remains constant.



6.2.0

Motor Considerations

- A machine with positive torque and positive speed *or* negative torque and negative speed functions as a motor.
- A machine with positive torque and negative speed or negative torque and positive speed functions as a brake or generator.



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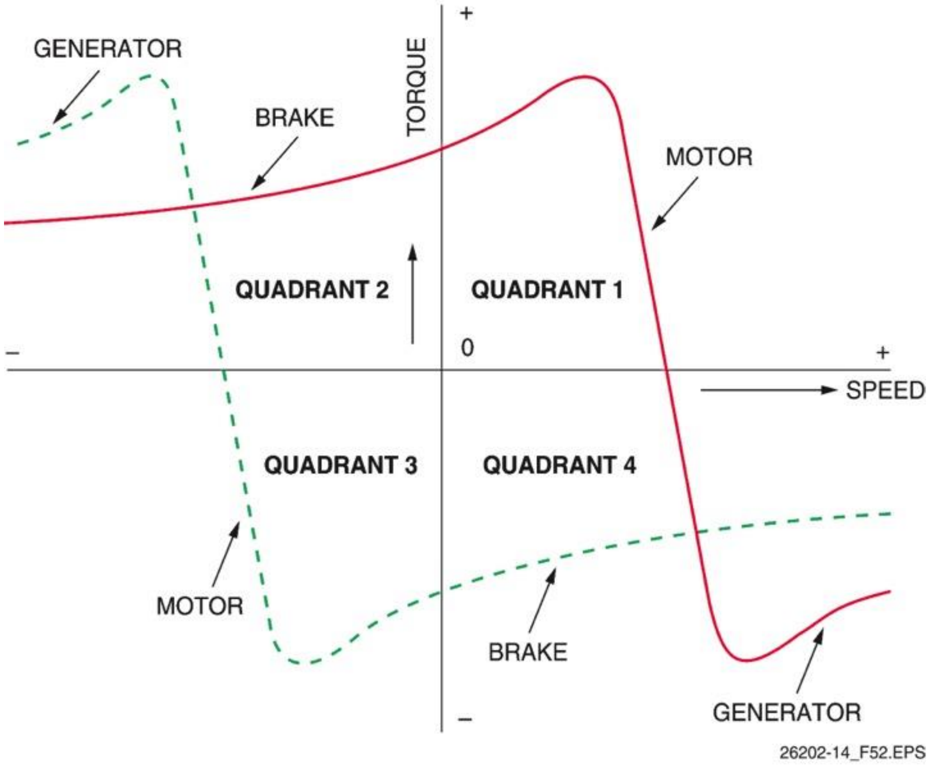
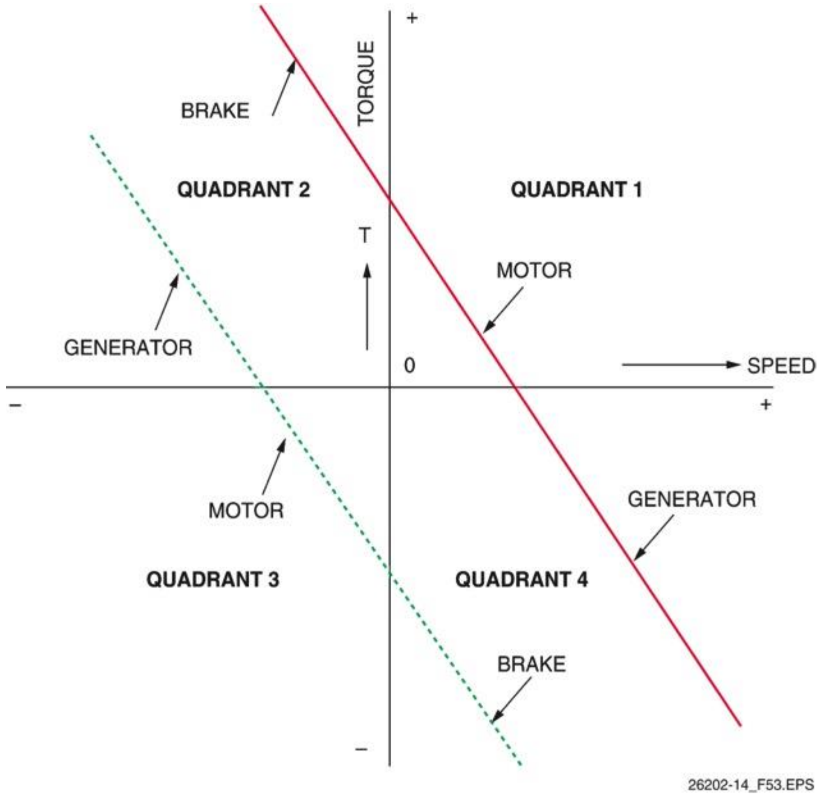
Typical Torque-Speed Curves

- When the stator leads are reversed, the motor switches between acting as a generator and acting as a brake in quadrants 2 and 4.
- It always acts as a motor in quadrants 1 and 3.



Four-Quadrant Operation for a DC Motor

- A DC shunt motor operates in the same quadrants, with the dotted line representing reversed armature leads.
- When using variable-speed drive systems, motor heating must be monitored to ensure effective cooling.



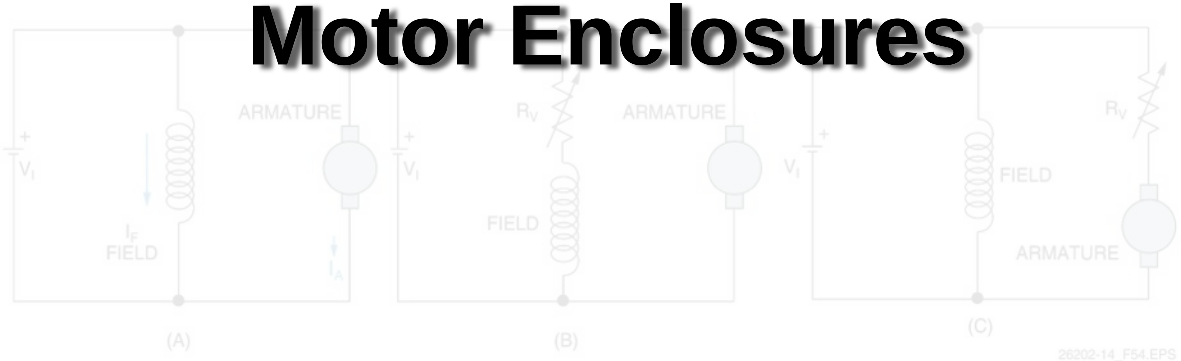
6.3.0 – 6.3.4

Next Sessions…

Motor Enclosures

Motor Speed Control

- The torque-speed characteristic can be shifted by varying the voltage applied to the field winding or the armature.
- As the field voltage is increased, the motor slows down.
- As the armature voltage is increased, the motor speeds up.



Performance Task

This session will conclude with trainees identifying various types of motors and their application(s).

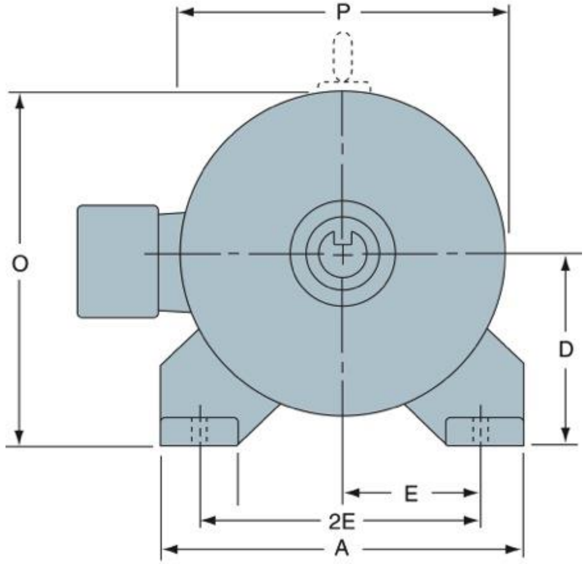
Motor Enclosures

Motor enclosures are classified by the National Electrical Manufacturers Association (NEMA) according to the degree of environmental protection provided and the method of cooling.

Open	Totally Enclosed
General purpose	Nonventilated
Drip-proof	Fan-cooled
Splash-proof	Fan-cooled guarded
Guarded	Explosion-proof
Semi-guarded	Dust- and ignition-proof
Drip-proof guarded	Pipe-ventilated
Externally ventilated	Water-cooled
Pipe-ventilated	Water-to-air-cooled
Weather-protected (Type I & Type II)	
Encapsulated windings	
Sealed windings	

NEMA Frame Designations

- NEMA developed standard frame sizes to ensure the interchangeability of motors built by different manufacturers.
- The distance from the motor feet to the shaft centerline is known as the D dimension.



(A)

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(B)

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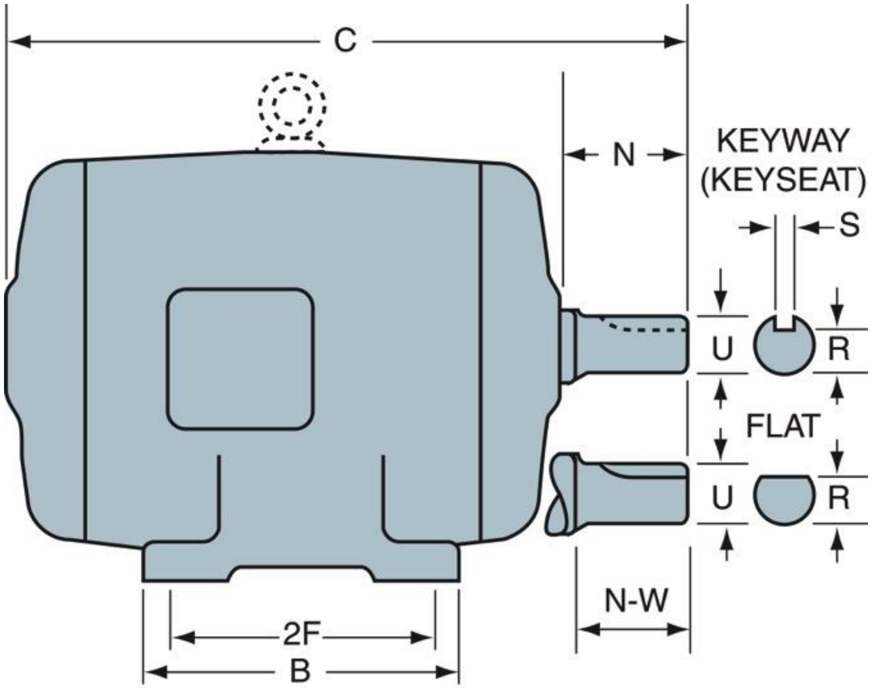
Lettering of Dimension Sheets for Foot-Mounted Machines (Side View)

- The center-to-center distance between front and back feet is known as the 2F dimension.
- The exposed shaft distance is called the N-W dimension.
- Manufacturer tables are available to correlate frame sizes with actual dimensions.



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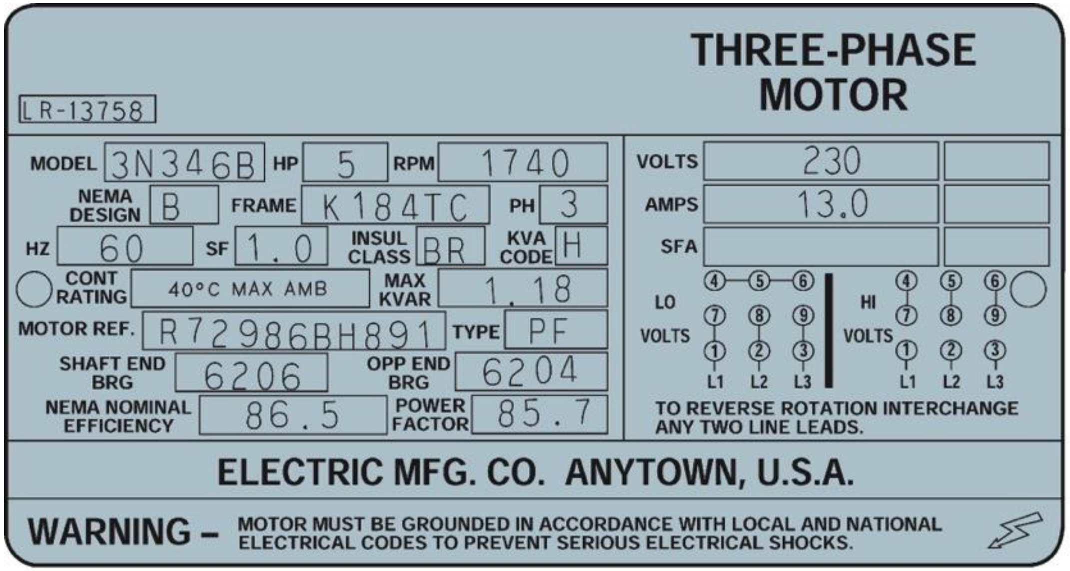
Frame Dimension Chart

Frame Number Series	Third/Fourth Digit in Frame Number							
	D	1	2	3	4	5	6	7
	2F Dimensions							
140	3.50	3.00	3.50	4.00	4.50	5.00	5.50	6.25
160	4.00	3.50	4.00	4.50	5.00	5.50	6.25	7.00
180	4.50	4.00	4.50	5.00	5.50	6.25	7.00	8.00
200	4.50	4.50	5.00	5.50	6.50	7.00	8.00	9.00
210	5.00	4.50	5.00	5.50	6.50	7.00	8.00	9.00
220	5.50	5.00	5.50	6.25	6.75	7.50	9.00	10.00
250	6.25	5.50	6.25	7.00	8.25	9.00	10.00	11.00
280	7.00	6.25	7.00	8.00	9.50	10.00	11.00	12.50
320	8.00	7.00	8.00	9.00	10.50	11.00	12.00	14.00
360	9.00	8.00	9.00	10.00	11.25	12.25	14.00	16.00
400	10.00	9.00	10.00	11.00	12.25	13.75	16.00	18.00
440	11.00	10.00	11.00	12.50	14.50	16.50	18.00	20.00
500	12.50	11.00	12.50	14.00	16.00	18.00	20.00	22.00
580	14.50	12.50	14.00	16.00	18.00	20.00	22.00	25.00
680	17.00	16.00	18.00	20.00	22.00	25.00	28.00	32.00

Frame Number Series	Third/Fourth Digit in Frame Number								
	D	8	9	10	11	12	13	14	15
	2F Dimensions								
140	3.50	7.00	8.00	9.00	10.00	11.00	12.50	14.00	16.00
160	4.00	8.00	9.00	10.00	11.00	12.50	14.00	16.00	18.00
180	4.50	9.00	10.00	11.00	12.50	14.00	16.00	18.00	20.00
200	5.00	10.00	11.00	. . .	. . .	. . .	. . .	. . .	. . .
210	5.25	10.00	11.00	12.50	14.00	16.00	18.00	20.00	22.00
220	5.50	11.00	12.50	. . .	. . .	. . .	. . .	. . .	. . .
250	6.25	12.50	14.00	16.00	18.00	20.00	22.00	25.00	28.00
280	7.00	14.00	16.00	18.00	20.00	22.00	25.00	28.00	32.00
320	8.00	16.00	18.00	20.00	22.00	25.00	28.00	32.00	36.00
360	9.00	18.00	20.00	22.00	25.00	28.00	32.00	36.00	40.00
400	10.00	20.00	22.00	25.00	28.00	32.00	36.00	40.00	45.00
440	11.00	22.00	25.00	28.00	32.00	36.00	40.00	45.00	50.00
500	12.50	25.00	28.00	32.00	36.00	40.00	45.00	50.00	56.00
580	14.50	28.00	32.00	36.00	40.00	45.00	50.00	56.00	63.00
680	17.00	36.00	40.00	45.00	50.00	56.00	63.00	71.00	80.00

9.0.0 – 9.1.19

Motor Ratings and Nameplate Data



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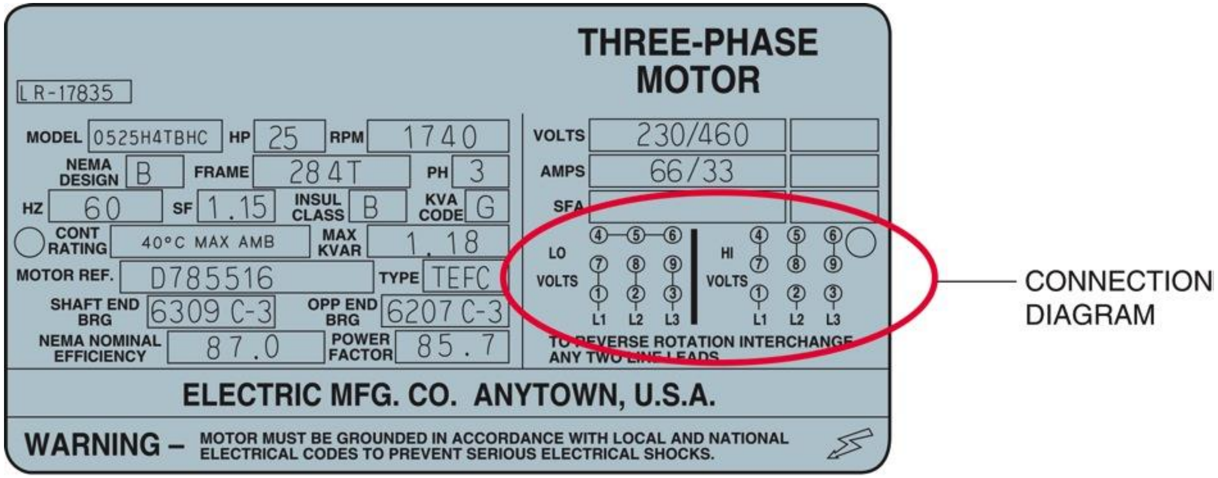
- ***NEC Section 430.7*** and *NEMA Standards MG-1* and *MG-2* list the requirements for motor nameplate data.
- The rated voltage on the nameplate is typically lower than that supplied by the electrical system.

Induction Motor Voltages

System Voltage	Rated Voltage
216	208
240	230
480	460
600	575
2,400	2,300
4,160	4,000
4,800	4,600
6,900 and 7,200	6,600
13,200 and 13,800	13,200

- Motor manufacturers assume there will be a 20V drop from the transformer down to the motor terminals.
- The nameplate voltage shows the most effective voltage for motor operation. Operation at other voltages may impact motor performance and service life.

High-Voltage and Low-Voltage Connection Diagrams Shown on Motor Nameplate



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- Some nameplates list both low-voltage and high-voltage connections (e.g., 230/460V).
- Motor nameplates for dual-voltage units typically include a connection diagram.

Motor Operation

Mode	Full-Load Current
110% of rated volts	7% decrease
90% of rated volts	11% increase
105% of rated frequency	5%–6% decrease
95% of rated frequency	5%–6% increase

- The full-load amps (FLA) rating on a motor nameplate represents the current the motor will draw at the nameplate horsepower, frequency, and voltage.
- The motor FLA is used to size the cable and overload/overcurrent devices in the circuit, but may vary depending on the actual voltage and frequency of the supply source.

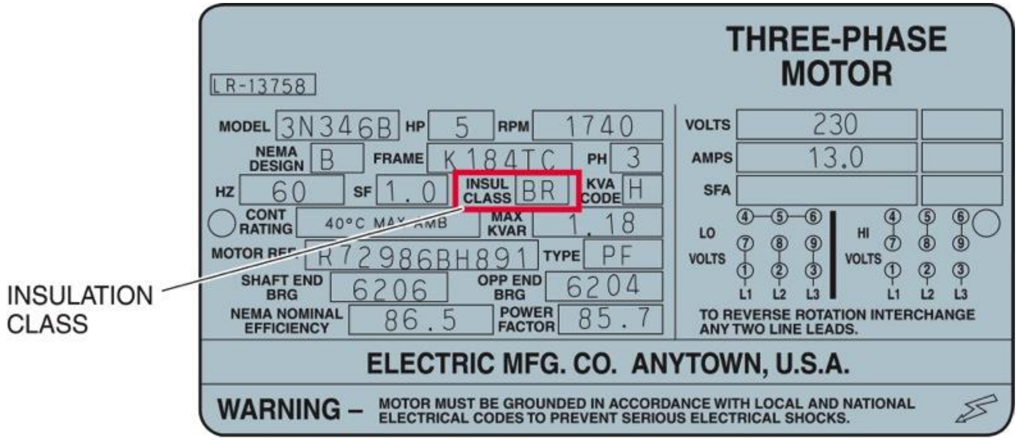
Typical Currents for 220V, 60-Cycle Squirrel Cage Motors

HP	Rated Full-Load Current	Starting (Maximum) Current	
		Classes B, C, D	Class F
½	2.0	12	—
1	3.5	24	—
1½	5.0	35	—
2	6.5	45	—
3	9	60	—
5	15	90	—
7½	22	120	—
10	27	150	—
15	40	220	—
20	52	290	—
25	64	365	—
30	78	435	270
40	104	580	360
50	125	725	450
60	150	870	540
75	185	1,085	675
100	246	1,450	900
125	310	1,815	1,125
150	360	2,170	1,350
200	480	2,900	1,800

- NEMA design letters define the starting torque characteristics of an induction motor. It is essential to match the design letter to the application. About 80% of industrial motors are NEMA Design B.
- The motor starting current is typically five to seven times the rated full-load current.

Nameplate Showing Insulation Class

- Premature failure of motor insulation is a leading cause of motor failure.
- NEMA specifies four different insulation classes for motors: A, B, F, and H. Class B is the most common type.
- The service factor indicates the amount of overload a motor can withstand. A typical service factor is 1.15.



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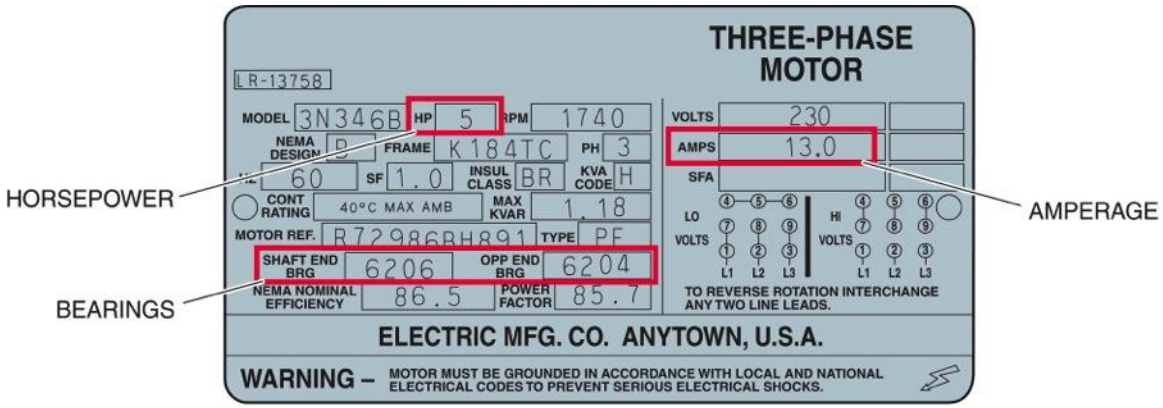
Locked-Rotor Code Letters

Code Letter	kVA Per Horsepower with Locked Rotor
A	0–3.14
B	3.15–3.54
C	3.55–3.99
D	4.0–4.49
E	4.5–4.99
F	5.0–5.59
G	5.6–6.29
H	6.3–7.09
J	7.1–7.99
K	8.0–8.99
L	9.0–9.99
M	10.0–11.19
N	11.2–12.49
P	12.5–13.99
R	14.0–15.99
S	16.0–17.99
T	18.0–19.99
U	20.0–22.39
V	22.4–AND UP

- The high current a motor draws on startup is called the inrush or locked-rotor current.
- The kVA code letter on the motor nameplate corresponds to a specific value of inrush current.

Nameplate Showing Bearings, Horsepower, and Amperage

- Polyphase motors require anti-friction or sleeve bearings (typically found in motors above 500hp).
- The rated amperage is the full-load current required to produce full-rated horsepower at the motor's rated voltage and frequency.
- The power factor (pf) measures efficiency and represents the ratio of active power to apparent power as measured on a meter.



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Motor Protection

- Fuses are normally used for motor overload protection.
- Where other devices such as trip coils or relays are used, the number of units can be determined using the data shown here.

Type of Motor	Supply System	Number and Location of Overload Units (such as trip coils or relays)
Single-phase AC or DC	Two-wire, single-phase AC or DC, ungrounded	One in either conductor
Single-phase AC or DC	Two-wire, single-phase AC or DC, one grounded conductor	One in ungrounded conductor
Single-phase AC or DC	Three-wire, single-phase AC or DC, grounded neutral	One in either ungrounded conductor
Single-phase AC	Any three-phase supply	One in ungrounded conductor
Two-phase AC	Three-wire, two-phase AC, ungrounded	Two, one in each phase
Two-phase AC	Three-wire, two-phase AC, one grounded conductor	Two, one in each ungrounded conductor
Two-phase AC	Four-wire, two-phase AC, grounded or ungrounded	Two, one per phase in ungrounded conductors
Two-phase AC	Five-wire, two-phase AC, grounded neutral or ungrounded	Two, one per phase in any ungrounded phase wire
Three-phase AC	Any three-phase supply	Three, one in each phase*

*Exception: An overload unit in each phase shall not be required where overload protection is provided by other approved means.

Duty Cycle Service

Protection for motors against overcurrents and ground faults can be determined using the data shown here.

	Percent of Full-Load Current			
Type of Motor	**Nontime Delay Fuse**	**Dual Element (Time Delay) Fuse****	**Instantaneous Trip Breaker**	**Inverse Time Breaker***
Single-phase motors	300	175	800	250
AC polyphase motors other than wound rotor:				
Squirrel cage:				
Other than Design B, energy efficient	300	175	800	250
Design B, energy efficient	300	175	1,100	250
Synchronous†	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

For certain exceptions to the values specified, see ***NEC Section 430.54***.

*The values given in the last column also cover the ratings of nonadjustable inverse time types of circuit breakers that may be modified per ***NEC Section 430.52***.

**The values in the Nontime Delay Fuse column apply to time-delay Class CC fuses.

†Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, etc., that start unloaded, do not require a fuse rating or circuit breaker setting in excess of 200% of the full-load current.

Next Session…

Connections and Terminal Markings for AC Motors

Motor Protection

- Thermal protectors are used to protect a motor from overloads and starting failures. All motors operating over 1,000V require a thermal protector.
- Protection for motors with special duty requirements can be determined using the data shown here.

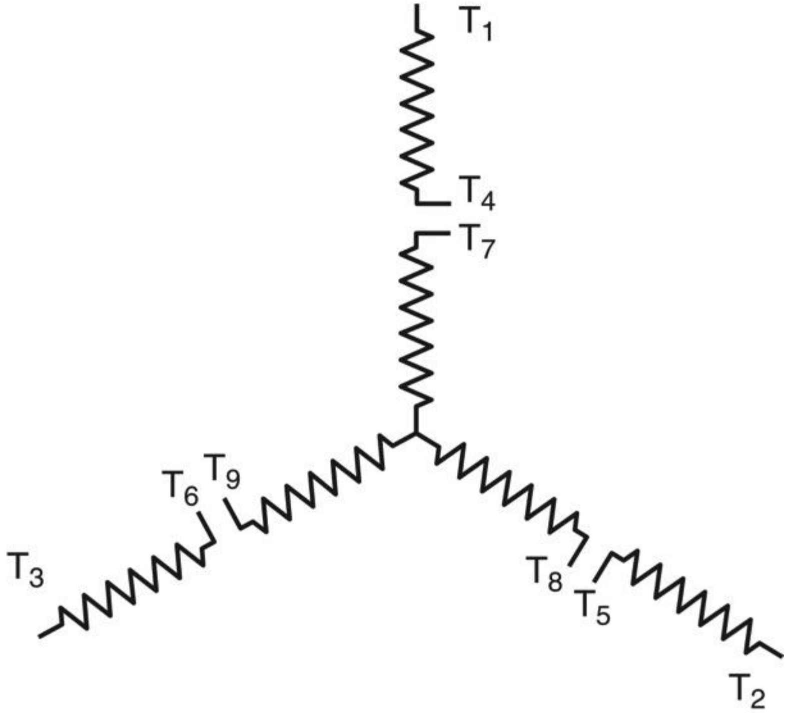
[illegible]	Percentages of Nameplate Current Rating			
	5-Minute [illegible]	[illegible] Rate[illegible] Moto[illegible]	30- and 60-[illegible]	Continuo[illegible]
Short-Time Duty				
[illegible] etc.	11[illegible]	120	[illegible]	—
Inte[illegible]				
Freight and passenger elevators, [illegible]heads, pumps, drawbridges, turntables, etc.				
For arc welders, see *NEC Section 630.11*	85	85	90	140
Periodic Duty				
Rolls, ore- and coal-handling machines, etc.	85	90	95	140
Varying Duty	110	120	150	200

Any motor application shall be considered as continuous duty unless the nature of the apparatus it drives is such that the motor will not operate continuously with load under any condition of use.

Performance Task

This session will conclude with trainees collecting data from a motor nameplate.

Connections and Terminal Markings for AC Motors



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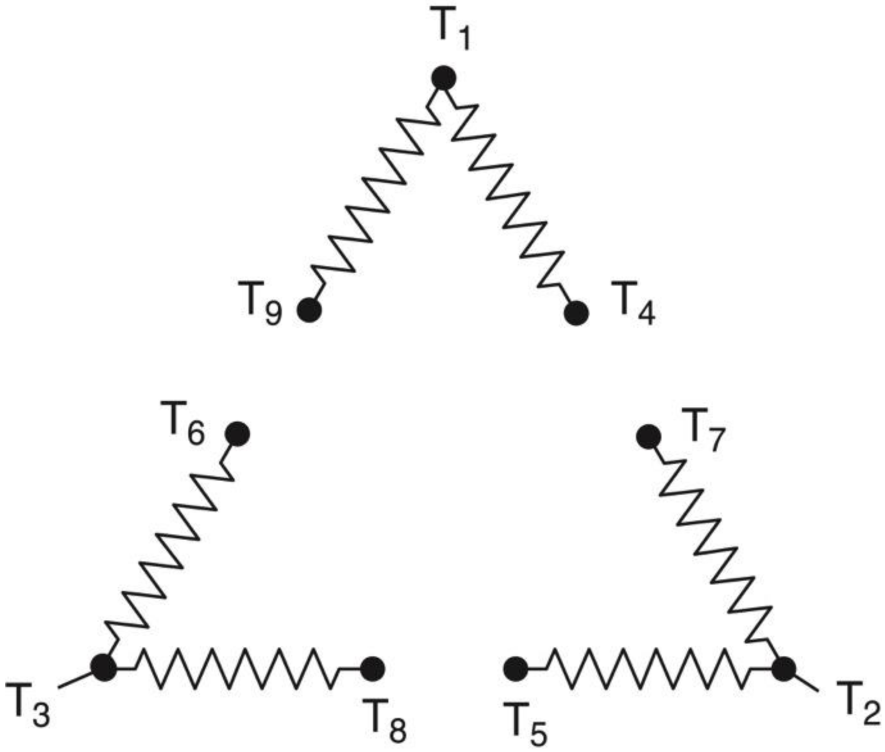
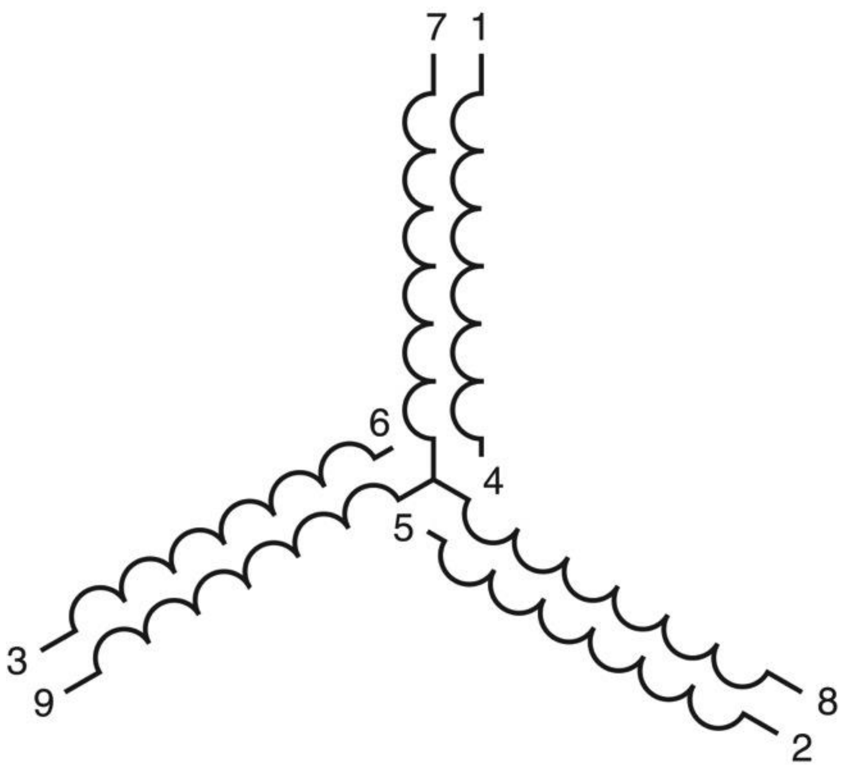
- In this wye-connected motor, three coils are connected and the other three are isolated.
- The leads can be grouped by testing them for continuity.

Dual-Voltage, Three-Phase Delta Connection



This delta-connected motor has three sets of two coils each connected together.

Identifying the Terminals of Wye-Connected Motors



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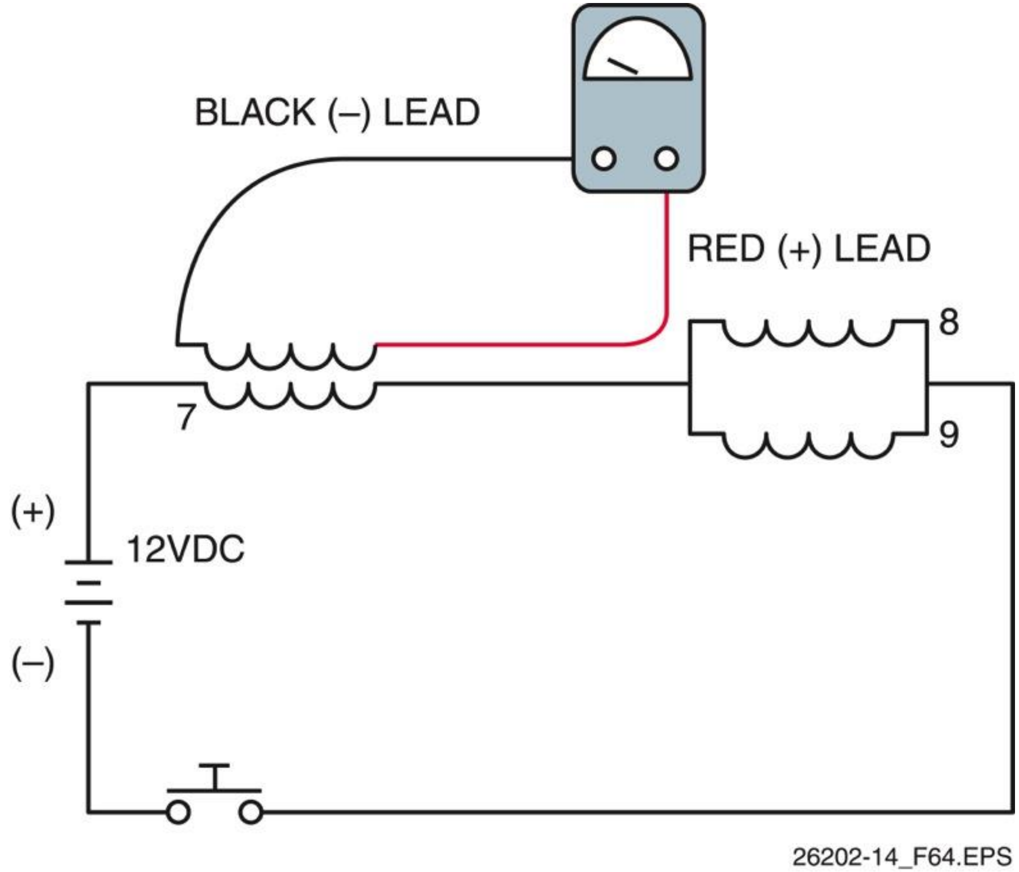
- It is often necessary to identify the leads when they have worn off on older or unlabeled motors.
- To begin, label the three common leads, then test the remaining leads using a DC voltmeter to find the lead with the highest voltage and those with positive and negative polarity.

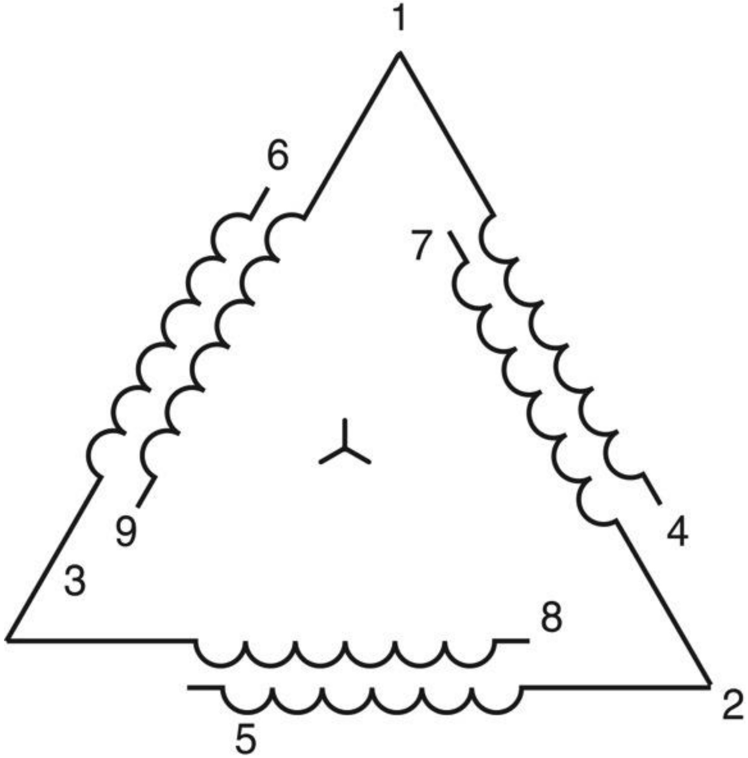
10.1.0

Battery Hookup for Wye-Connected Motor Lead Identification



Identifying the Terminals of Delta-Connected Motors

- To identify the terminals of a delta-connected motor, use an ohmmeter on a low scale to measure the resistance between each of the three leads in one group. The lead that shows the least resistance will be lead 1.
- Continue to test the remaining leads using an ohmmeter to identify the leads by measuring their resistance.



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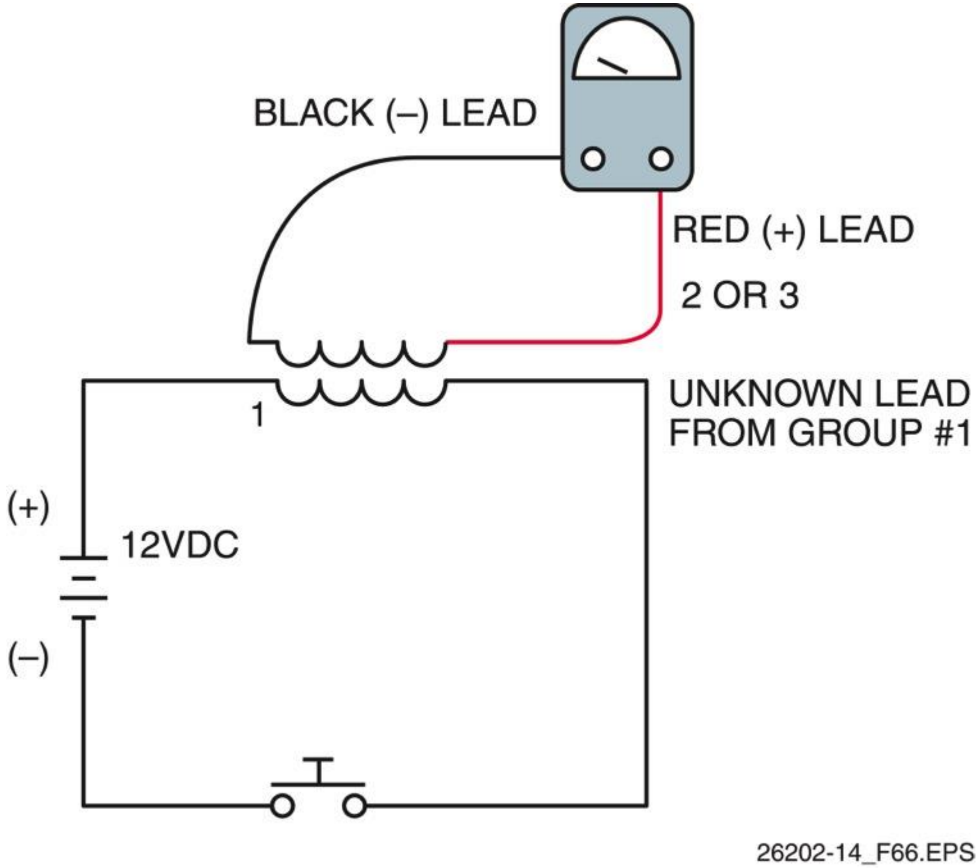
Battery Hookup for Delta-Connected Motor Lead Identification



Performance Task

This session will conclude with trainees connecting the terminals for a dual-voltage motor.

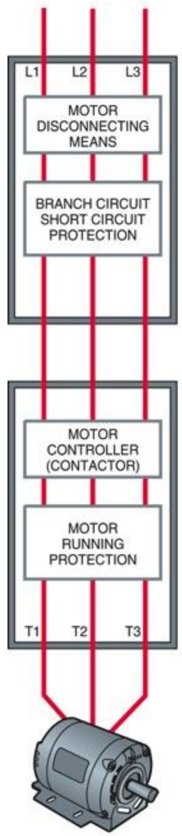
11.0.0 – 13.0.0

NEC® Requirements; Braking; Motor Installation

Review the *NEC*® requirements for motors as covered in ***NEC Articles 430 and 440***.

Application	Requirement	*NEC*® Reference
Location	Motors must be installed in areas with adequate ventilation. They must also be arranged so that sufficient work space is provided for replacement and maintenance.	*NEC Section 430.14(A)*
	Open motors must be located or protected so that sparks cannot reach combustible materials.	*NEC Section 430.14(B)*
	In locations where dust or flying material will collect on or in motors in such quantities as to seriously interfere with the ventilation or cooling of motors and thereby cause dangerous temperatures, suitable types of enclosed motors that will not overheat under the prevailing conditions must be used.	*NEC Section 430.16*
Disconnecting means	A motor disconnecting means must be within sight from the controller location (with exceptions) and disconnect both the motor and controller. The disconnect must be readily accessible and clearly indicate the OFF/ON positions (open/closed).	*NEC Article 430, Part IX* *NEC Section 430.104*
	Motor control circuits require a disconnecting means to disconnect them from all supply sources.	*NEC Section 430.75*
	The disconnecting means must be as specified in the code.	*NEC Section 430.109*
Wiring methods	Flexible connections such as Type AC cable, Greenfield, flexible metal tubing, etc., are standard for motor connections.	*NEC Articles 300 and 430*
Motor control circuits	All conductors of a remote motor control circuit outside of the control device must be installed in a raceway or otherwise protected. The circuit must be wired so that an accidental ground in the control device will not start the motor.	*NEC Section 430.73*
Guards	Exposed live parts of motors and controllers operating at 50 volts or more must be guarded by installation in a room, enclosure, or other location so as to allow access by only qualified persons, or elevated 8 feet or more above the floor.	*NEC Section 430.232*
Adjustable speed drive systems	Requirements for adjustable speed drives and their motors.	*NEC Article 430, Part X*
Motors operating over 1,000 volts	Special installation rules apply to motors operating at over 1,000 volts.	*NEC Article 430, Part XI*
Controller grounding	Motor controller enclosures must be grounded.	*NEC Section 430.244*

Summary of Requirements for Motors, Motor Circuits, and Controllers



NEC Article 430, Part IX Sections 430.101 through 430.113

Disconnects motor and controllers from circuit.

1. Continuous rating of 115% or more of motor FLC. Also see *NEC Article 430, Part II*.
2. All disconnecting means in the motor circuit must be per *NEC Sections 430.108, 430.109, and 430.110*.
3. Must be located in sight of motor location and driven machinery. The controller disconnecting means can serve as the disconnecting means if the controller disconnect is located in sight of the motor location and driven machinery.

NEC Article 430, Part IV Sections 430.51 through 430.58

Protects branch circuit from short circuits or grounds.

1. Must carry starting current of motor.
2. Rating must not exceed values in *NEC Table 430.52* unless not sufficient to carry starting current of motor.
3. Values of branch circuit protective devices shall in no case exceed exceptions listed in *NEC Section 430.52*.

NEC Article 430, Part VII Sections 430.81 through 430.90

Used to start and stop motors.

1. Must be able to interrupt LRC.
2. Must be rated as specified in *NEC Section 430.83*.

NEC Article 430, Part III Sections 430.31 through 430.44

Protects motor and controller against excessive heat due to motor overload.

1. Must trip at following percent or less of motor FLC for continuous motors rated more than one horsepower.
   a) 125% FLC for motors with a marked service factor of not less than 1.15 or a marked temperature rise of not over 40°C.
   b) 115% FLC for all others. (See the *NEC®* for other types of protection.)
2. Three thermal units required for any three-phase AC motor.
3. Must allow motor to start.
4. Select size from FLC on motor nameplate.

NEC Article 430, Part II Sections 430.21 through 430.29

Specifies the sizes of conductors capable of carrying the motor current without overheating.

1. To determine the ampacity of conductors, switches, branch circuit overcurrent devices, etc., the full-load current values given in *NEC Tables 430.247 through 430.250* shall be used instead of the actual current rating marked on the motor nameplate. *(See NEC Section 430.6.)*
2. According to *NEC Section 430.22*, branch circuit conductors supplying a single motor used in a continuous duty application shall have an ampacity of not less than 125% of motor FLC, as determined by *NEC Section 430.6(A)(1)*.

26202-14_F67.EPS

11.0.0 – 13.0.0

Next Session…

Installing Motors

26202-14_SA07.EPS

Wrap Up

- A wet motor must be dried and tested before starting.
- Always follow the manufacturer's instructions when installing motors.
- A micrometer can be used to achieve precise alignment during motor installation.

Wrap Up

3-2-1

3 – Write **3** important things learned during class

2 – Write **2** questions you have about the material

1 – Write **1** thought you had about the material

Next Session…

MODULE EXAM

Review the complete module to prepare for the module exam. Complete the Module Review as a study aid.