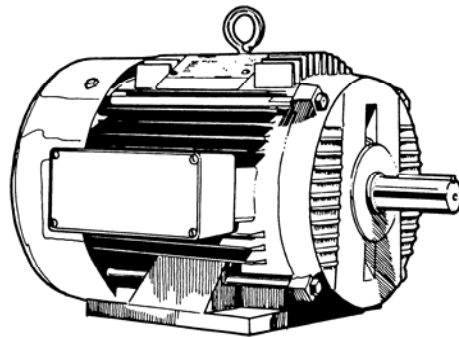


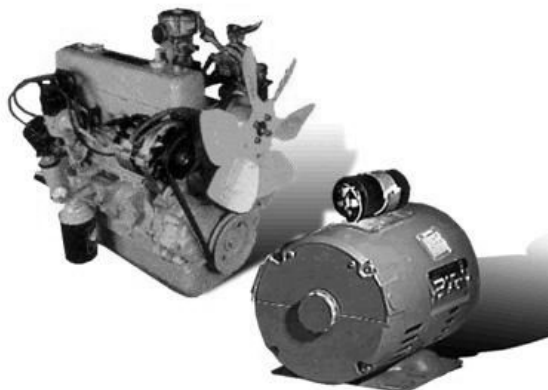
Motor Basics

AGSM 325



Motors vs Engines

- Motors convert electrical energy to mechanical energy.
- Engines convert chemical energy to mechanical energy.

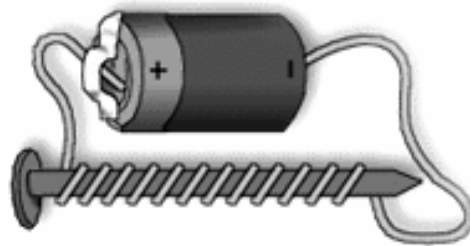


Motors

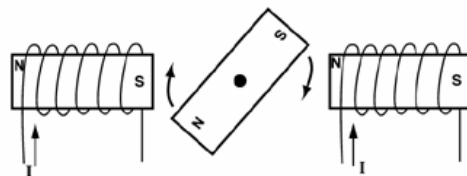
- Advantages
 - Low Initial Cost - \$/Hp
 - Simple & Efficient Operation
 - Compact Size – cubic inches/Hp
 - Long Life – 30,000 to 50,000 hours
 - Low Noise
 - No Exhaust Emissions
 - Withstand high temporary overloads
 - Automatic/Remote Start & Control
- Disadvantages
 - Portability
 - Speed Control
 - No Demand Charge

Magnetic Induction

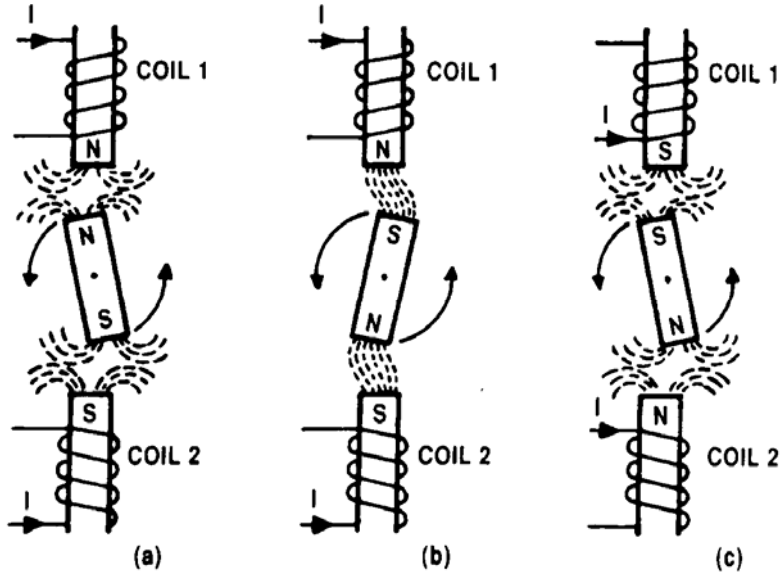
- Simple Electromagnet



- Like Poles Repel
- Opposite Poles Attract



Operating Principle



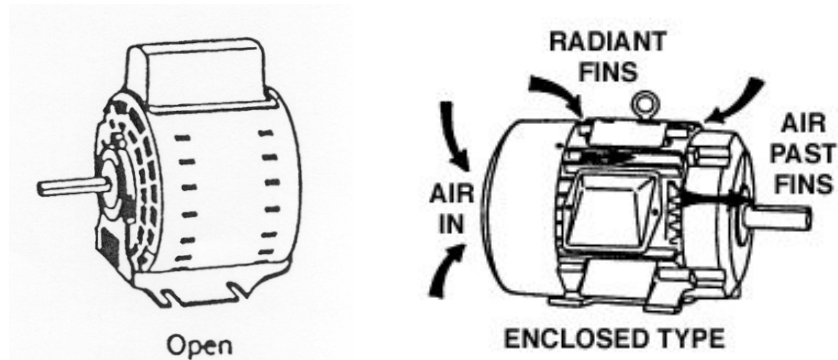
Motor Parts

- Enclosure
- Stator
- Rotor
- Bearings
- Conduit Box
- Eye Bolt



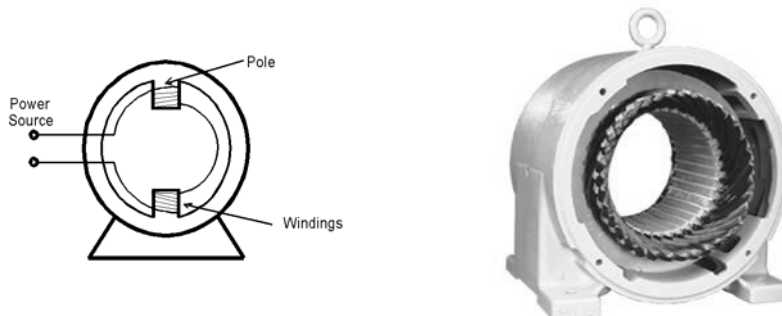
Enclosure

- Holds parts together
- Helps with heat dissipation
- In some cases, protects internal components from the environment.



Stator (Windings)

- “Stationary” part of the motor sometimes referred to as “the windings”.
- Slotted cores made of thin sections of soft iron are wound with insulated copper wire to form one or more pairs of magnetic poles.



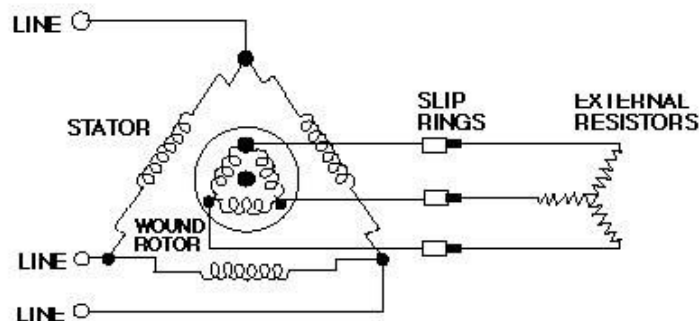
Rotor

- “Rotating” part of the motor.
- Magnetic field from the stator induces an opposing magnetic field onto the rotor causing the rotor to “push” away from the stator field.



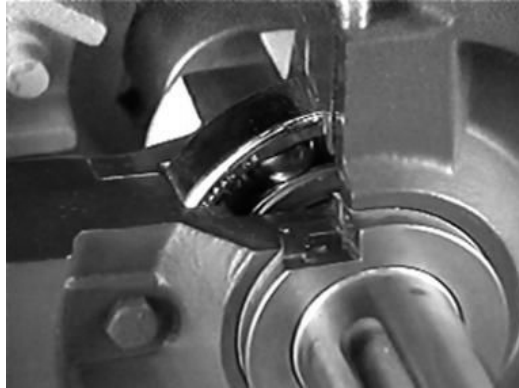
Wound Rotor Motors

- Older motor designed to operate at “variable speed”
- Advantages
 - Speed Control, High Starting Torque, Low Starting Current
- Disadvantages
 - Expensive, High Maintenance, Low Efficiency



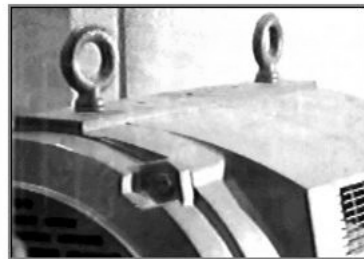
Bearings

- Sleeve Bearings
 - Standard on most motors
 - Quiet
 - Horizontal shafts only
 - Oil lubricated
- Ball (Roller) Bearings
 - Support shaft in any position
 - Grease lubricated
 - Many come sealed requiring no maintenance



Other Parts

- Conduit Box
 - Point of connection of electrical power to the motor's stator windings.
- Eye Bolt
 - Used to lift heavy motors with a hoist or crane to prevent motor damage.



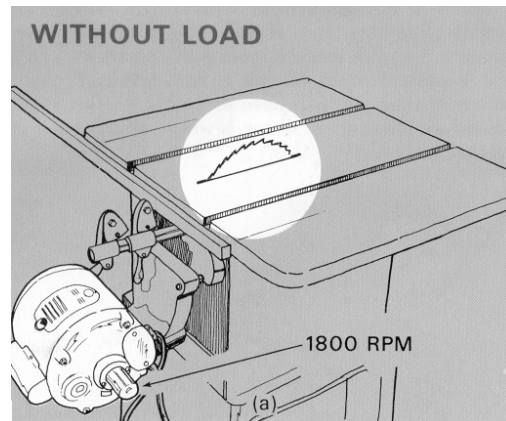
Motor Speed

- Synchronous Speed
 - Speed the motor's magnetic field rotates.
 - Theoretical speed with not torque or friction.
- Rated Speed
 - Speed the motor operates when fully loaded.
 - Actual speed at full load when supplied rated voltage.



Synchronous Speed

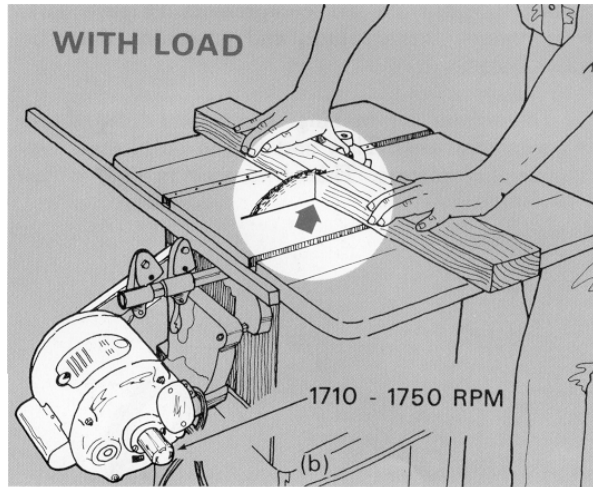
- Theoretical Speed
- A well built motor may approach synchronous speed when it has no load.
- Factors
 - Electrical Frequency (cycles/second)
 - # of poles in motor



$$\text{Synchronous Speed} = \frac{120 \times \text{Frequency}}{\text{\# of Poles}}$$

Rated Speed

- Speed the motor runs at when fully loaded and supplied rated nameplate voltage.



Motor Slip

- Percent difference between a motor's synchronous speed and rated speed.
- The rotor in an induction motor lags slightly behind the synchronous speed of the changing polarity of the magnetic field.
 - Low Slip Motors
 - “Stiff”....High Efficiency motors
 - High Slip Motors
 - Used for applications where load varies significantly...oil pump jacks.

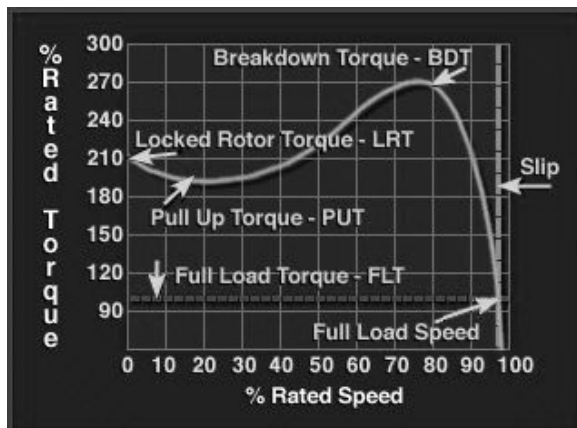
Torque

- Measure of force producing a rotation
 - Turning Effort
 - Measured in pound-feet (foot-pounds)



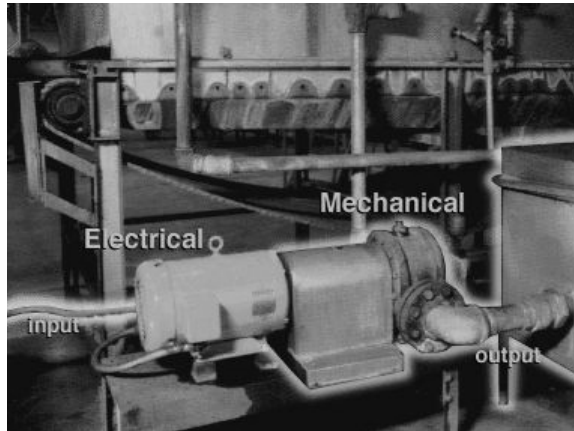
Torque-Speed Curve

- Amount of Torque produced by motors varies with Speed.
- Torque Speed Curves
 - Starting Torque
 - Pull Up Torque
 - Breakdown Torque



Motor Power

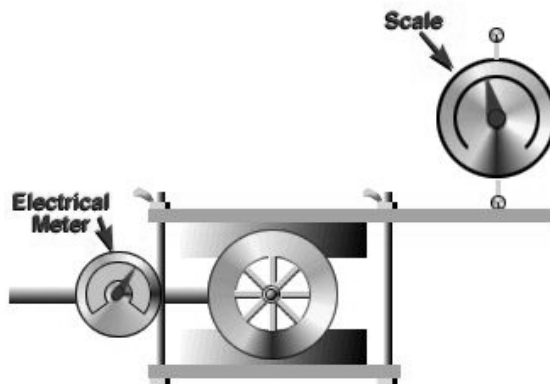
- Output Power
 - Horsepower
 - Amount of power motor can produce at shaft and not reduce life of motor.
- Input Power
 - Kilowatts
 - Amount of power the motor consumes to produce the output power.



Calculating Horsepower

$$\text{HP} = \text{RPM} \times \text{TORQUE} / 5252$$

- Need Speed and Torque
- Speed is easy
 - Tachometer
- Torque is difficult
 - Dynamometer
 - Prony Brake



Watt's Law

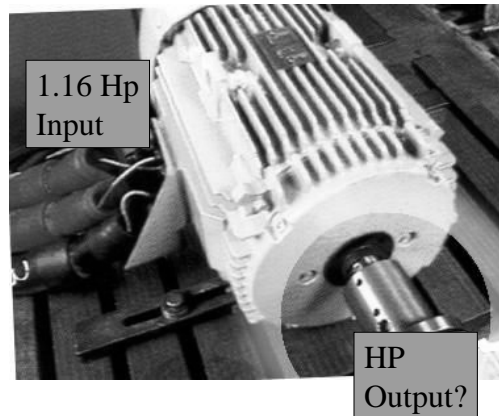
- Input Power
- Single Phase
 - Watts = Volts X Amps X p.f.
- Three Phase
 - Watts = Avg Volts X Avg Amps X p.f. X 1.74

Example

- Is a 1 Hp 1-phase motor driving a fan overloaded?
 - Voltage = 123 volts
 - Current = 9 amps
 - p.f. = 78%
- Watts = Volts X Amps X p.f.
 - Watts = 123 volts X 9 amps X 0.78 = 863.5 Watts
 - 864 Watts / 746 Watts/Hp = 1.16 Hp
- Is the motor overloaded?

Electrical = Input

- We measured Input
- Motors are rated as Output
- Difference?
 - Efficiency
- If the motor is 75% efficient, is it overloaded?
- $\text{Eff} = \text{Output} / \text{Input}$
- $\text{Output} = \text{Eff} \times \text{Input}$
 $0.75 \times 1.16 \text{ Hp} = 0.87 \text{ Hp}$
- The motor is NOT overloaded

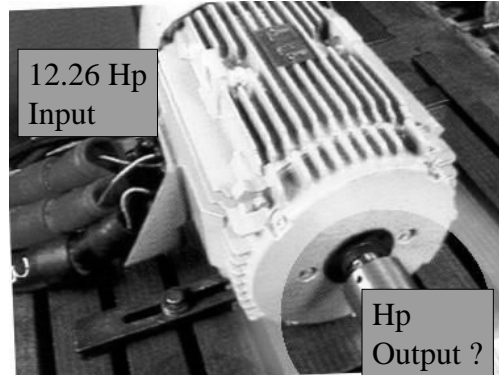


Example #2

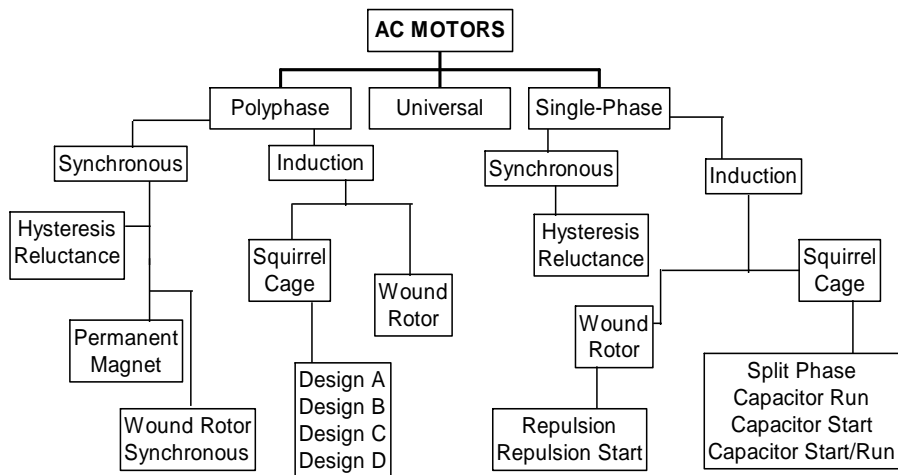
- Is this 10 Hp, 3-phase motor overloaded?
 - Voltages = 455, 458, and 461 volts
 - Currents = 14.1, 14.0 and 13.9 amps
 - P.f. = 82%
- $\text{Watts} = \text{Volts}_{\text{avg}} \times \text{Amps}_{\text{avg}} \times \text{p.f.} \times 1.74$
 $\text{Watts} = 458\text{v} \times 14\text{a} \times 0.82 \times 1.74 = 9148.6 \text{ Watts}$
 $9148.6 \text{ Watts} / 746 \text{ Watts/Hp} = 12.26 \text{ Hp}$
- Is the motor overloaded?

Example #2

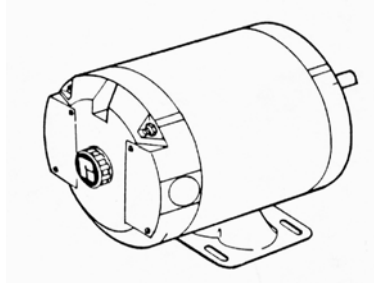
- We measured Input
- Motor is rated as Output
- Difference?
 - Efficiency
- If the motor is 90% efficient, is it overloaded?
- $\text{Eff} = \text{Output} / \text{Input}$
- $\text{Output} = \text{Eff} \times \text{Input}$
 $0.90 \times 12.26 \text{ Hp} = 11.0 \text{ Hp}$
- The motor IS overloaded!
- How bad is the overload?



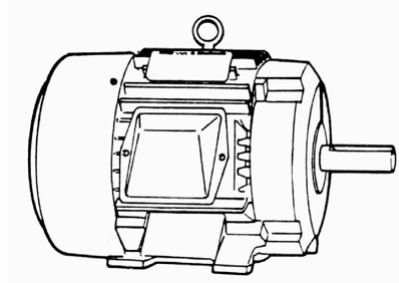
Motor Types CLASSIFICATION OF MOTORS



Synchronous vs Induction Motors



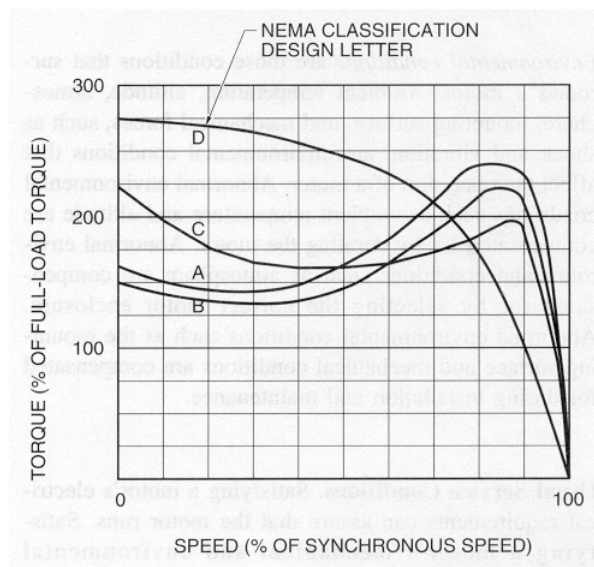
- Synchronous Motors
 - Turn at exactly the same speed as the rotating magnetic field.
 - 3600 rpm, 1800 rpm, etc.



- Induction Motors
 - Turn at less than synchronous speed under load.
 - 3450 rpm, 1740 rpm, etc.

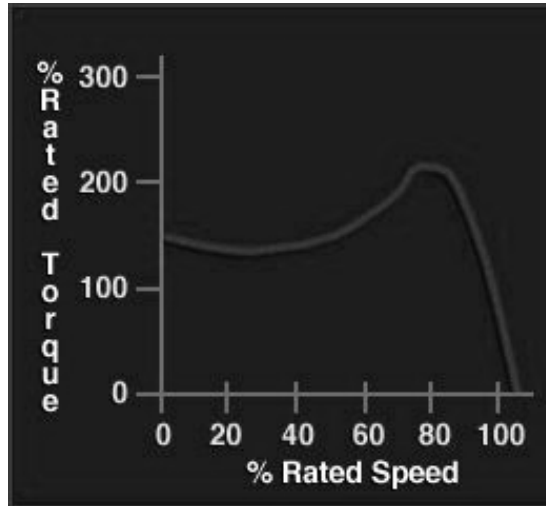
NEMA 3 Phase Motors

- 3 Phase Induction Motors
- NEMA Torque-Speed Design Types
 - A,B,C,D,E



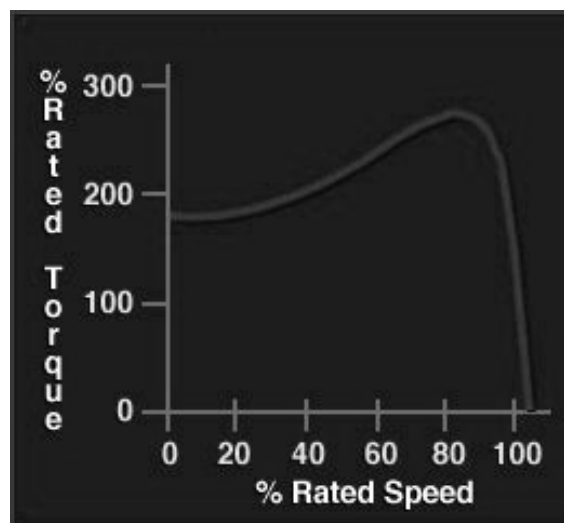
Design Type B

- Today's "Standard" 3-Phase Motor
- Good Starting Torque
 - In-rush amps 4-6 times full load amps
 - Good breakdown-torque
 - Medium Slip



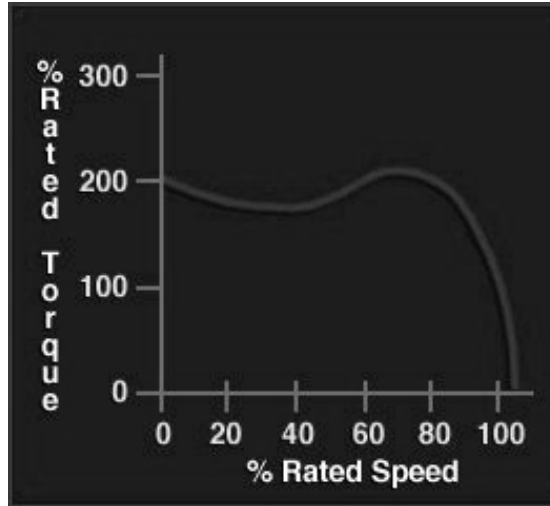
Design Type A

- The "old" Standard
- Higher starting torque than "B".
- Higher in-rush current (5-8 times full load amps)
- Good breakdown torque



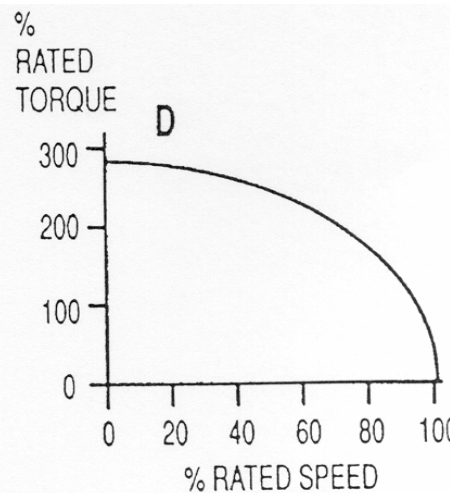
Design Type C

- Common OEM equipment on reciprocating pumps, compressors and other “hard starting” loads.
- High starting torque
- Moderate starting current (5-8 times FLA)
- Moderate breakdown torque



Design Type D

- Common on applications with significant loading changes as a machine operates.
- Impact Loads
 - Punch Presses, Metal Shears, etc.
 - Pump Jacks



Design Type E

- Newest NEMA Category
- Newer ultra-high efficiency motors
 - Higher Starting Torque
 - Higher Starting Current (8-12 times Running)
 - Ultra Low Slip (Higher Rated Speed)

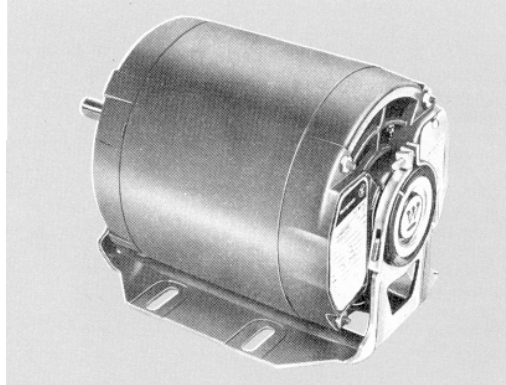
Single Phase Induction Motors

- Are not “self starting”
 - Require a starting mechanism.
- The name generally describes its “starting mechanism”.
 - Split Phase
 - Capacitor Run
 - Capacitor Start
 - Capacitor Start-Capacitor Run
 - Shaded Pole
 - Synchronous
 - Universal



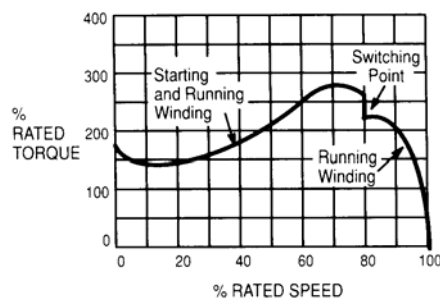
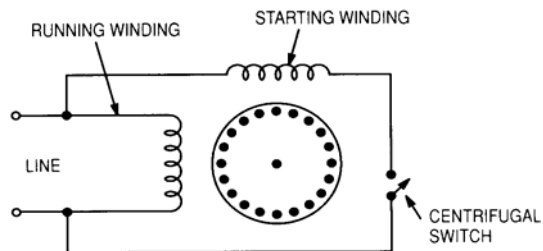
Split Phase Motor

- Common small single phase motor
 - Good Starting Torque
 - Moderate Efficiency
 - Moderate Cost
- Small conveyors, augers, pumps, and some compressors
- 1/20th to 3/4 Hp, available to 1.5 Hp



Split Phase Motor

- Starting winding in parallel with Running winding
- Switch operates at 70-80% of full speed.
- Centrifugal Switch
 - Sticks Open
 - Sticks Shut



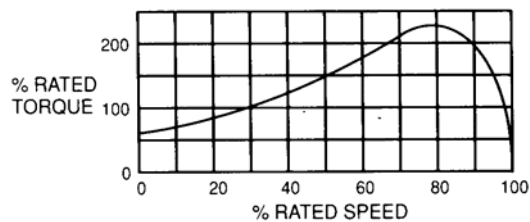
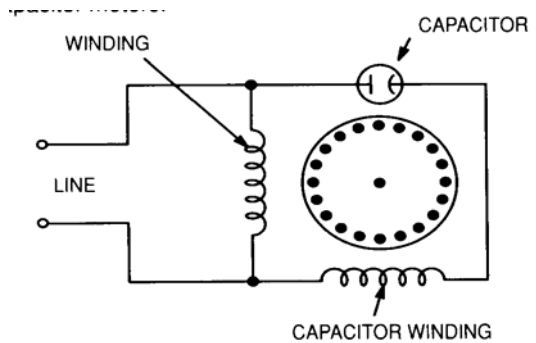
Capacitor Run Motor (Permanent Split Capacitor or PSC)

- Primarily a fan and blower motor.
- Poor starting torque
- Very low cost motor.



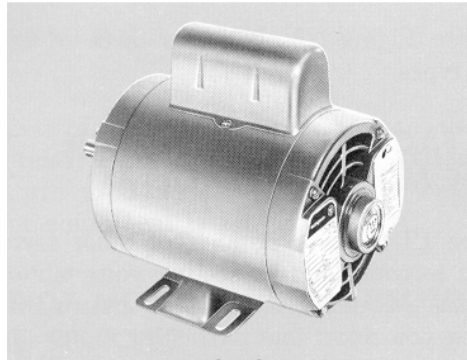
Permanent Split Capacitor (PSC)

- Capacitor in “Capacitor Winding”
 - Provides a “phase shift” for starting.
 - Optimizes running characteristics.
- No centrifugal switch



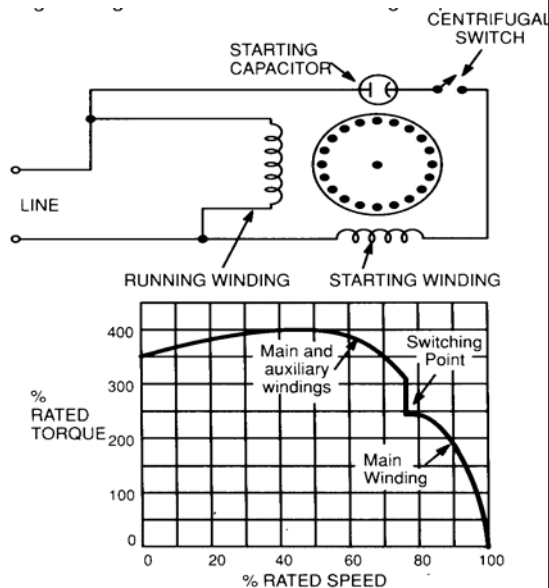
Capacitor Start Motor

- Larger single phase motors up to about 10 Hp.
- A split phase motor with the addition of a capacitor in the starting winding.
- Capacitor sized for high starting torque.



Capacitor Start Motor

- Very high starting torque.
- Very high starting current.
- Common on compressors and other hard starting equipment.



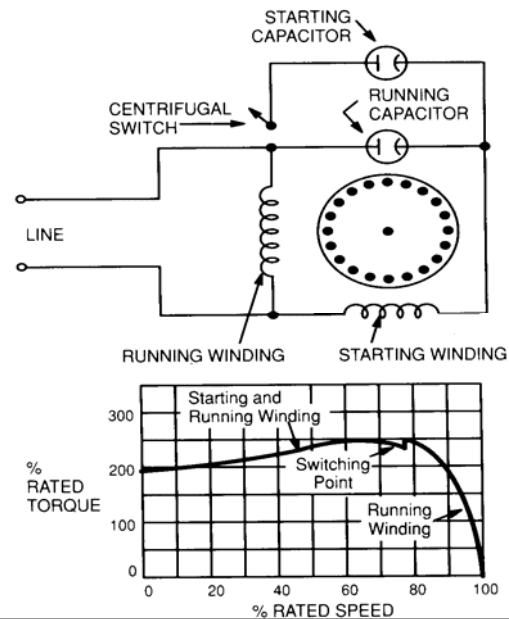
Capacitor Start-Capacitor Run

- Both starting and running characteristics are optimized.
 - High starting torque
 - Low starting current
 - Highest cost
- For hard starting loads like compressors and pumps.
- Up to 10 Hp or higher in some situations.



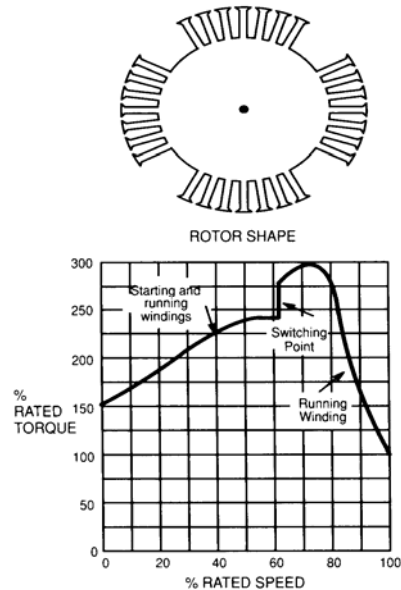
Capacitor Start-Run Motor

- Larger single phase motors up to 10 Hp.
- Good starting torque (less than cap start) with lower starting current.
- Higher cost than cap start.



Synchronous Motor

- Special design for “constant speed” at rated horsepower and below.
- Used where maintaining speed is critical when the load changes.



Universal Motor

- Runs on AC or DC
- Commutator and brushes
- Generally found in portable power tools.
- Lower Hp sizes



Universal Motor

- Very high starting torque.
- Higher torque on DC than AC (battery operated tools)
- The higher the rpm, the lower the torque.

