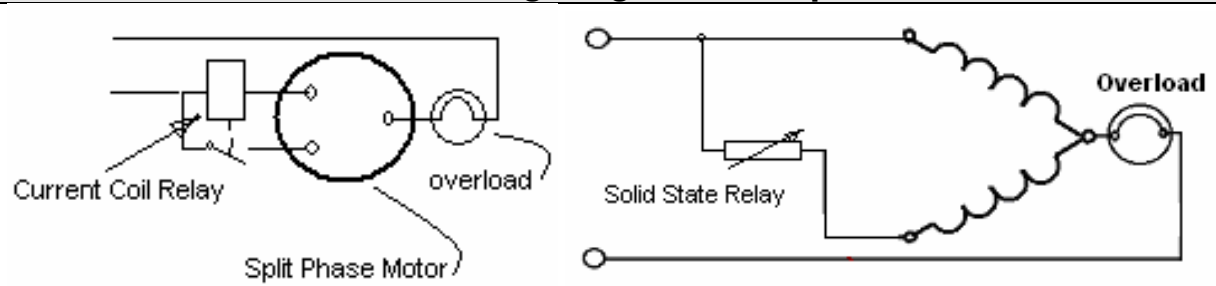
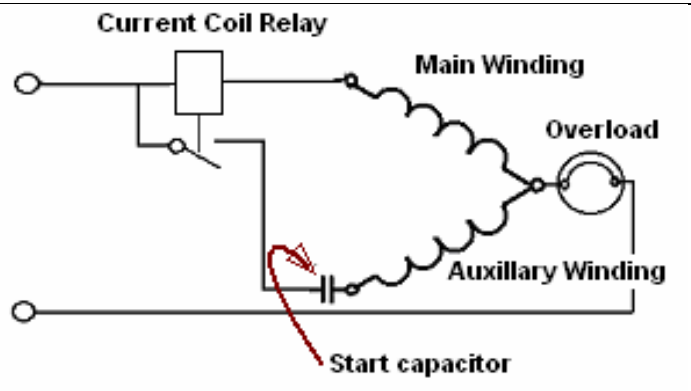
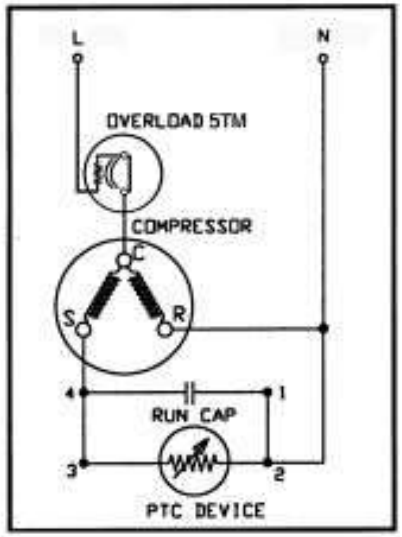
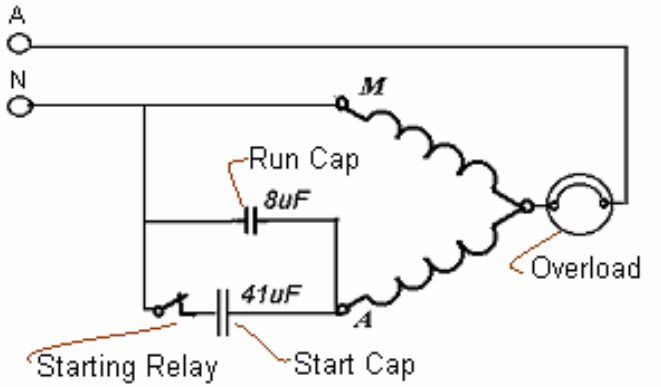
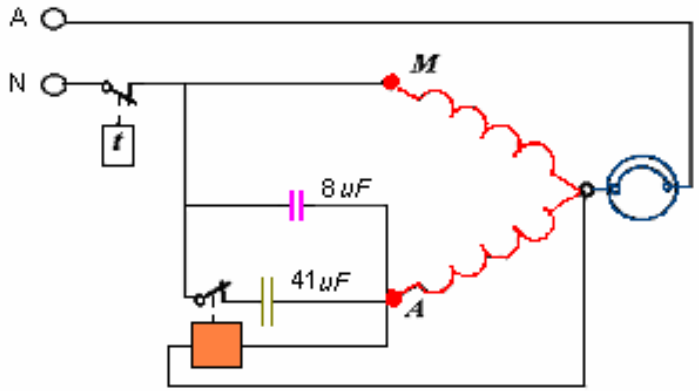
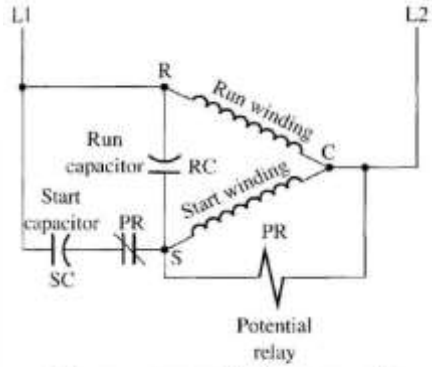
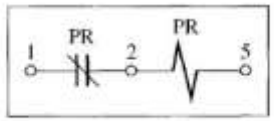
Refrigeration and Air Conditioning Motor Types

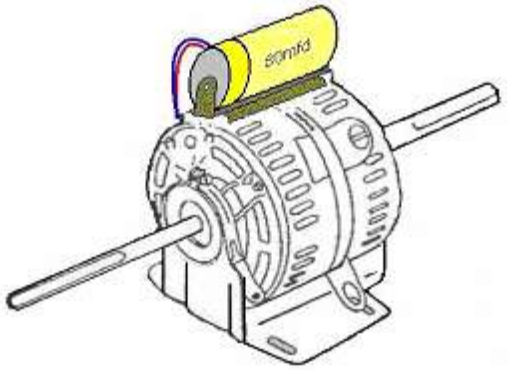
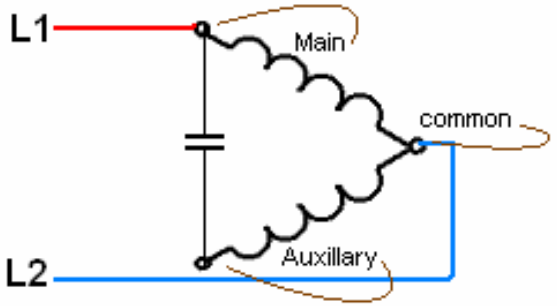
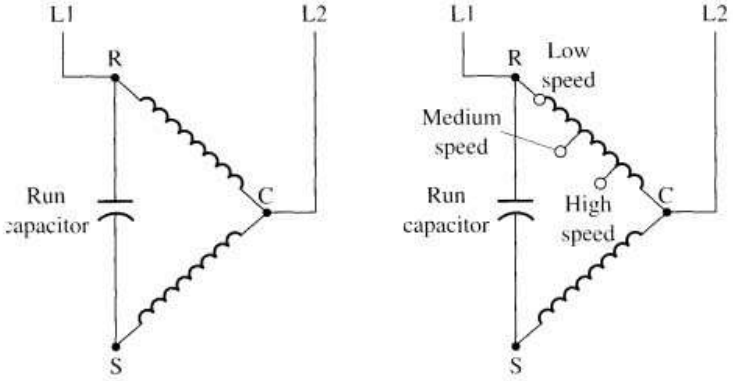
Compressor Starting Matrix

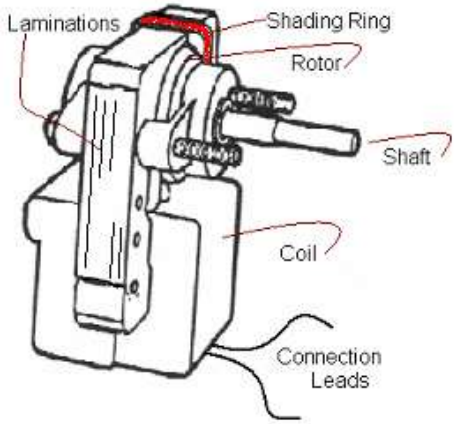
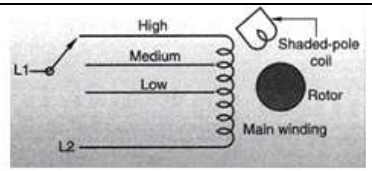
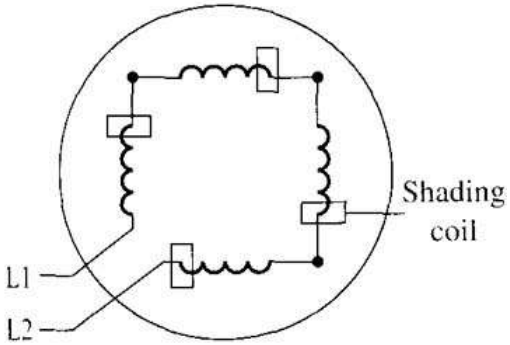
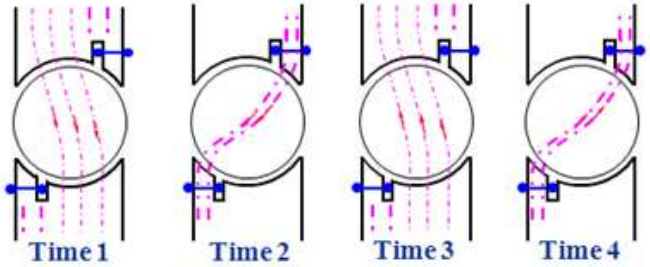
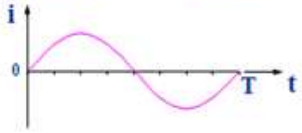
Motor Type	Overload Protector	Starting Device			Capacitors	
		Current Relays	Voltage Relays	PTC	Start	Run
Split phase Induction Motor (RSIR)	Yes	Yes		Yes		
Cap Start Induction Run (CSIR)	Yes	Yes			Yes	
Resistance start Cap run motor (RSCR)	Yes			Yes		Yes
Permanent Split Capacitor (PSC)	Yes					Yes
Cap start Cap run CSCR	Yes		Yes		Yes	Yes
Three phase motor (3ϕ)	Yes					

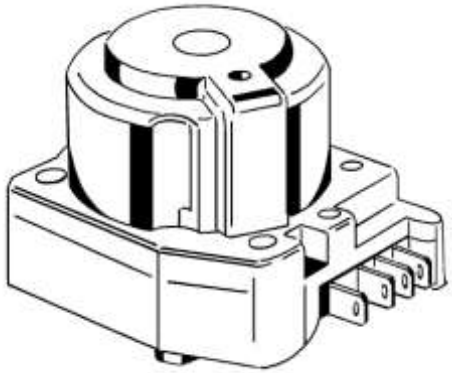
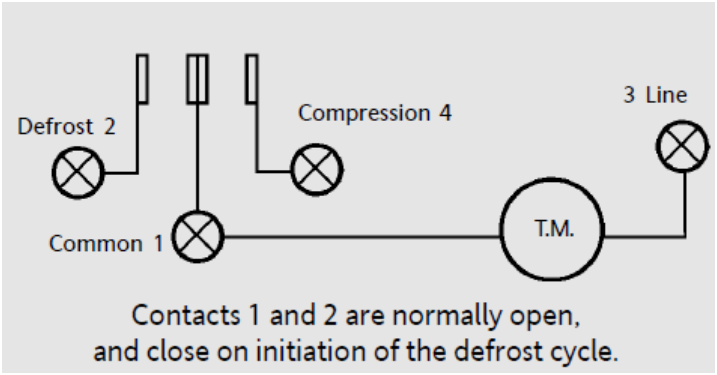
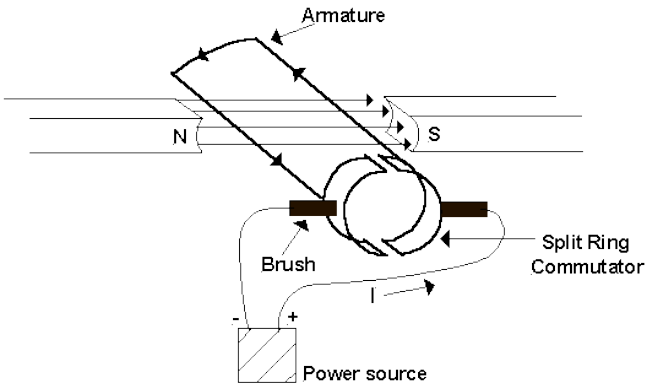
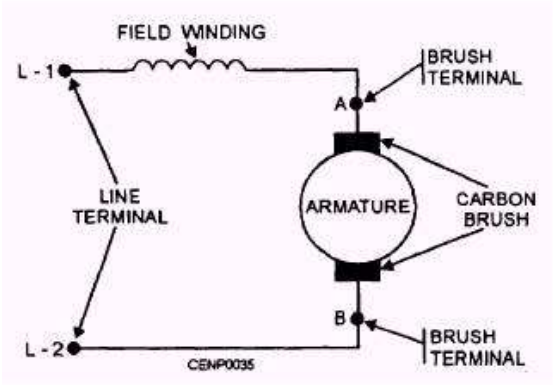
Type	Starting Device	Wiring diagram / Sample
Resistance Start Induction Run (RSIR) **Split Phase induction motors**	Current Relay or Solid State Small motors with low starting torque – ideal for capillary systems where system pressure equalizes on the off cycle.	

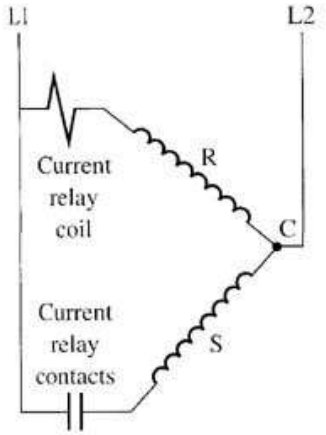
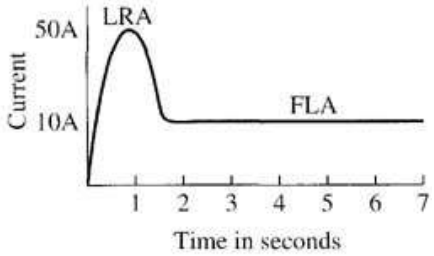
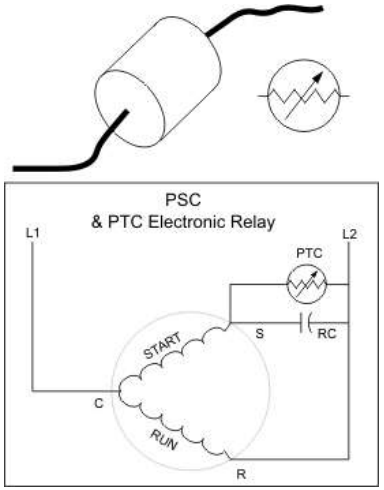
Capcitor Start Induction Run (CSIR) Current start relay and start capacitor	The start capacitor is connected to the start winding in the motor The motor starts using both windings, but as the motor in the CSIR system comes up to speed, the relay removes the start winding and the start capacitor from the circuit. This happens in about one-third of a second, and the motor then runs on the run winding alone with no capacitor.	
Resistance Start Capacitor Run (RSCR)	Similar to RSIR motor version but has a PTC solid state starting device and permanent connected run capacitor to improve efficiency. Run cap stays in circuit after start up.	

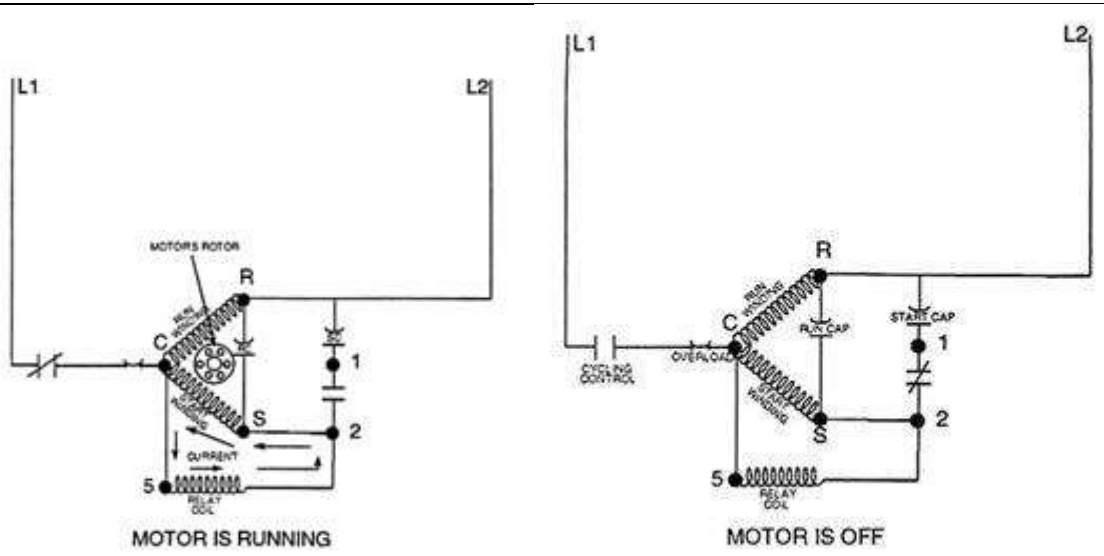
Capacitor Start Capacitor Run (CSCR) Potential relay and adds a run capacitor to the start capacitor, which provides the motor with better torque characteristics when the motor is operating at full speed. The capacitor start, capacitor run motor is used primarily in starting large single- phase hermetic compressors	Prior to the motor's start, both the start and run capacitors are connected to the start winding. The motor in the CSCR system reaches operating speed in about one-third of a second. And once again, the start capacitor is removed from the circuit, just as in the CSIR motor. In this case, however, the run capacitor and the start winding remain in the circuit, and the motor runs using both windings.	 NRE 8 Three Phase/Signal Phase Motors and Circuits Compiled by Bruce Davison, Greg Riach & Robert Baker  Capacitor Start Capacitor Run with Potential Coil Relay  (a) Diagram of potential relay connected to a capacitor start, capacitor run motor  (b) Diagram of potential relay

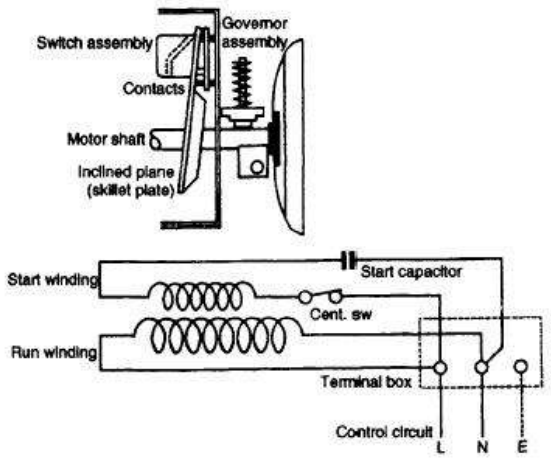
Permanent Split Capacitor (PSC) Single winding - no relay, low torque	The permanent split-capacitor (PSC) motor uses only a run capacitor in parallel with the windings to provide the phase shift required to start the motor. Commonly used as evaporator fans in ducted AC units.	  NRE 8 Three Phase/Signal Phase Motors and Circuits Compiled by Bruce Davison, Greg Riach & Robert Baker  (a) Single-speed PSC motor (b) Multispeed PSC motor http://www.industrial-electronics.com/AC-DC-motors/54_Permanent-Split-Capacitor-Motors.html

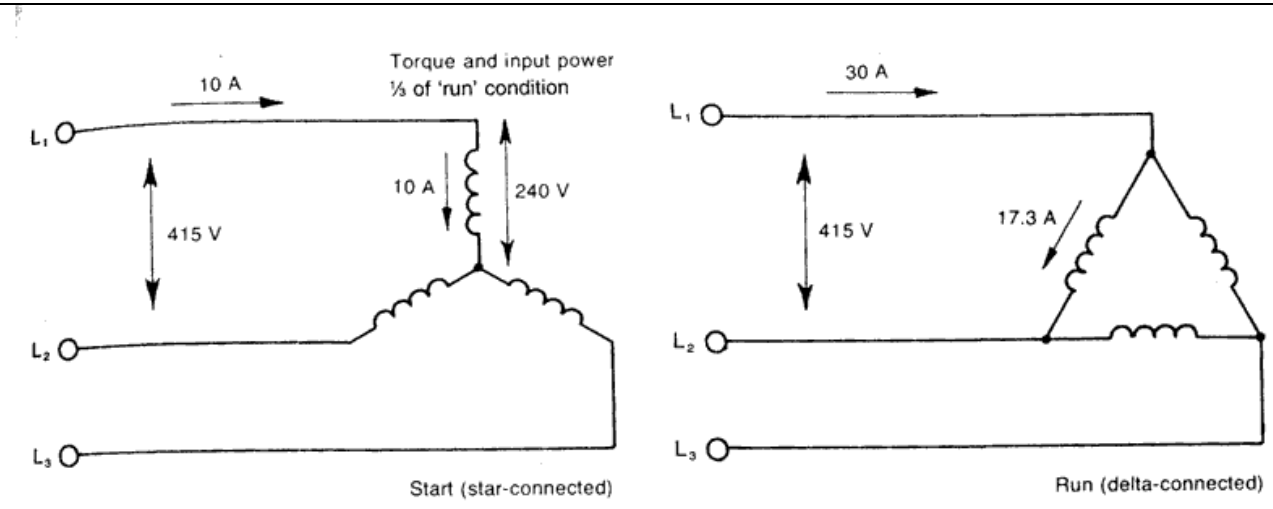
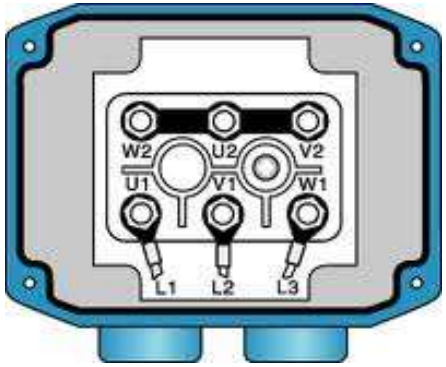
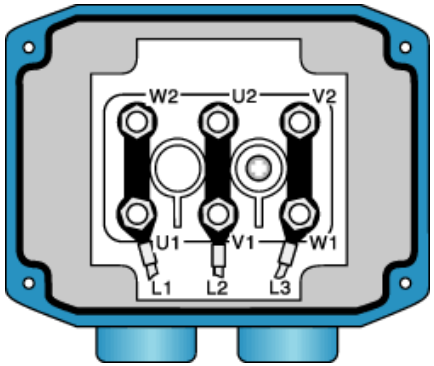
Shaded Pole	Commonly found in applications that require light-duty fans such as small window air conditioners, evaporators and exhaust fans used in rest rooms. Note that the motor has only one winding. It doesn't have a start winding and a run winding like other single-phase motors.	    **Shaded pole motor. Can be single-speed, or tapped multispeed as shown here. Electrically and mechanically simple, it is inexpensive, but has poorest efficiency and starting torque. Best uses are usually household rather than industrial.** NRE 8 Three Phase/Signal Phase Motors and Circuits Compiled by Bruce Davison, Greg Riach & Robert Baker    http://www.industrial-electronics.com/AC-DC-motors/57_Shaded-Pole-Motors.html johnsonmotor.com

Synchronous	When using fixed frequency AC these motors maintain constant speed and are therefore used in clocks and other devices requiring a constant rate of rotation Defrost Timers are designed to control the defrost cycle of a refrigerator or a freezer	  http://www.toolbox.invensyscontrols.com/appliance/linkedElements/DefrostTimers.pdf
Universal (commutator)	ac or dc Universal motors are used in vacuum cleaners, sewing machines, food mixers and portable tools.	 webs.mn.catholic.edu.au  Universal motor schematic. http://www.tpub.com/ceb/109.htm

Current Relays	In series with the run winding and operates a set of contacts in the start winding. The high current at start up energises the coil to close the contacts and allow current to flow through the start winding	 (a) Compressor motor  (b) 
Positive Temperature Co-efficient (PTC) Relays	A PTC solid state starting device is placed in series with the start winding and normally has a very low resistance. On startup, as current starts to flow to the start winding, the resistance rapidly rises to a very high value thus reducing the start winding current to a trickle and effectively taking that winding out of operation.	   http://www.hvacrinfo.com/Tecumseh_bulletins/compressor.pdf

Potential or Voltage Relays	**A**. When the power is applied through the cycling control, both the run and start windings are energized. The start and run capacitors provide the phase shift for starting torque because of their capacitance adding when wired in parallel. In fact, both capacitors are wired in series with the start winding and in parallel with the run winding. The run capacitor also limits the current that will pass through the start winding when the motor is running, since they are wired in series. The run capacitor also provides running torque when the motor is up and running. **B**. The operation of the potential starting relay is based on the increase in back electromotive force (back EMF) or a bucking voltage that is generated across the start winding as the motor increases in speed.	 Pictures courtesy http://hvacreducationtechtips.blogspot.com.au/2009/06/potential-starting-relay.html C. The large metal mass of the motor's rotor turning at high speeds with motor windings in close proximity has a voltage generating effect This generated back EMF opposes line voltage and can be measured across the start winding or across the coil of the potential relay at terminals 2 and 5. The back EMF is usually a higher voltage than the line voltage and can be in the 400-V range. All motors have different magnitudes of back EMF **D.**The back EMF voltage generated across the start winding causes a small current to flow in the start winding and in the potential relay coil since they are in the same circuit. When the back EMF has built up to a high enough value, referred to as pick-up voltage, the contacts between terminals 1 and 2 will be picked-up opened. This will take the start capacitor out of the circuit. The pickup voltage usually occurs when the motor has reached about 3/4 speed

Centrifugal Switch This form of starting device is used on open drive motors and is also found on vacuum pumps and many other motor types.	It comprises three major components: the switch contacts, the moving contact arm and the governor assembly (see Figure 41). The switch contacts are wired in series with the supply and the start winding. The governor assembly is mounted on the motor shaft. It consists of a spring loaded weight on a small rod. The spring loaded contact arm has a circular inclined plane extending around the shaft; this is commonly known as the skillet plate. When the motor is idle, the switch contacts are closed. When the motor starts, the shaft rotates, gathers speed and sets up a strong centrifugal force which causes the weight to move outwards against the spring tension. This permits the contact arm to move and open the switch contacts, thus disconnecting the start circuit. http://www.refrigeratortroubleshoot.com/refrigerator-centrifugal-switch.html	 **Figure 41** *Centrifugal switch*  Vacuum pump rotor and centrifugal switch Photo taken by Paul Marshall Skills Tech Bracken Ridge **Video of the operation of a centrifugal switch** http://www.youtube.com/watch?feature=player_embedded&v=39nflq5XbBA

3 Phase Motors	Wiring Diagrams and connections • excellent starting torque • a wide operating voltage range • no ancillary starting devices (relays, capacitors) Reduced starting load on any individual phase, and minimal impact on nearby lighting, etc. The use of a three phase compressor may be essential to comply with local regulations relating to starting current limits. A suitable contactor, preferably incorporating thermal protection, is necessary to switch a three phase compressor. A three phase reciprocating compressor is designed to run in either direction, therefore phase connections can be made in any sequence	 **Fig. 13.1** *Comparison of star and delta starting* patchn.com  Star Connection  Delta Connection (http://www.johnson-pump.com/Horticulture/quickstart-motor.htm