

Refrigeration & Air Conditioning Technology
SIXTH EDITION

SECTION 4

ELECTRIC MOTORS

UNIT 17: TYPES OF ELECTRIC MOTORS

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UNIT OBJECTIVES

After studying this unit, the reader should be able to

- Describe the different types of open single-phase motors used to drive fans, compressors, and pumps.
- Describe the applications of the various types of motors.
- State which motors have high starting torque.
- List the components that cause a motor to have a higher starting torque.
- Describe a multispeed permanent split-capacitor motor and indicate how the different speeds are obtained.

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UNIT OBJECTIVES

After studying this unit, the reader should be able to

- Explain the operation of a three-phase motor.
- Describe a motor used for a hermetic compressor.
- Explain the motor terminal connections in various compressors.
- Describe the different types of compressors that use hermetic motors.
- Describe the use of variable-speed motors.

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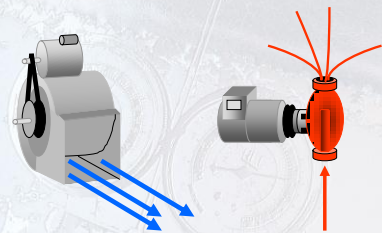
USES OF ELECTRIC MOTORS

- Used to turn fans, pumps and compressors
- Facilitate the circulation of air, water, refrigerant and other fluids
- Motors are designed for particular applications
- The correct motor must always be used
- Most motors operate on similar principles

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Fans are used to move air



Pumps are used to move liquids

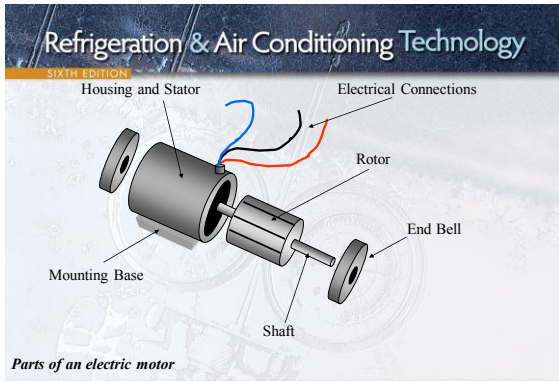
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PARTS OF AN ELECTRIC MOTOR

- Stator with motor windings – Stationary portion of the motor
- Rotor – Rotating portion of the motor
- Bearings – Allow free rotation of the motor shaft
- End bells – Supports the bearings and/or shaft
- Housing – Holds all motor components together and facilitates motor mounting

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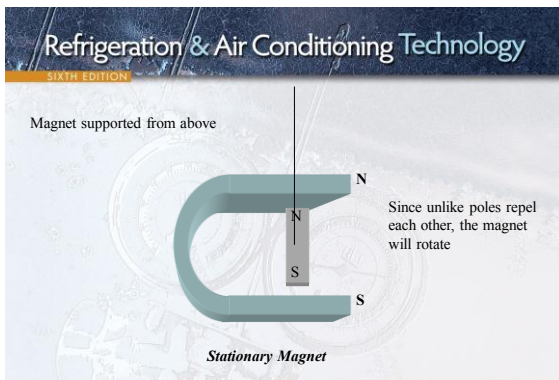
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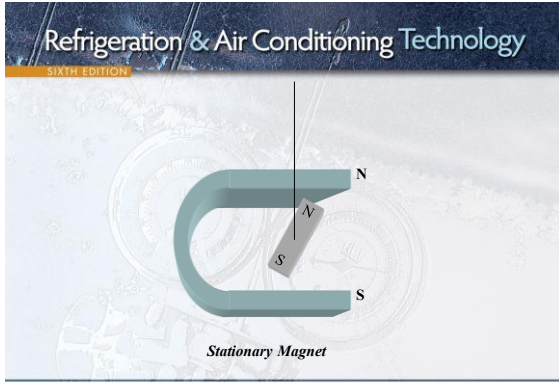
ELECTRIC MOTORS AND MAGNETISM

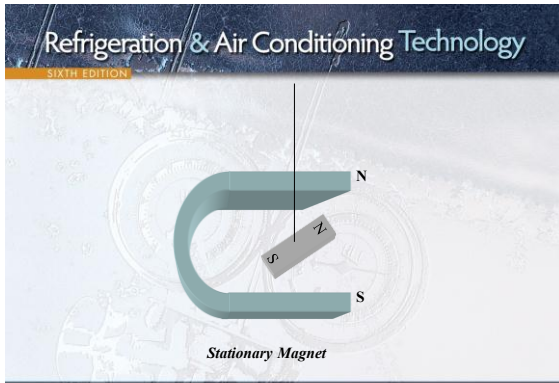
- Electricity and magnetism are used to create rotation
- Stator has insulated windings called run windings
- Rotor may be constructed of bars
 - Squirrel cage rotor
 - Positioned between the run windings
- Rotor turns within the magnetic field

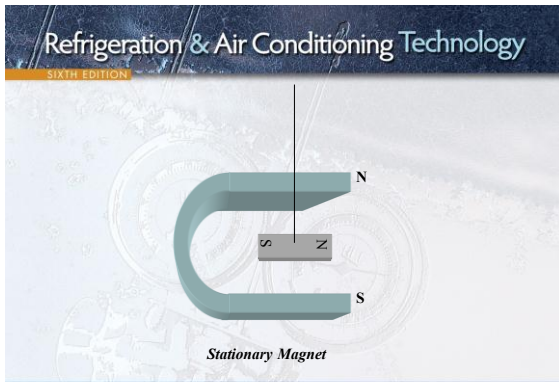
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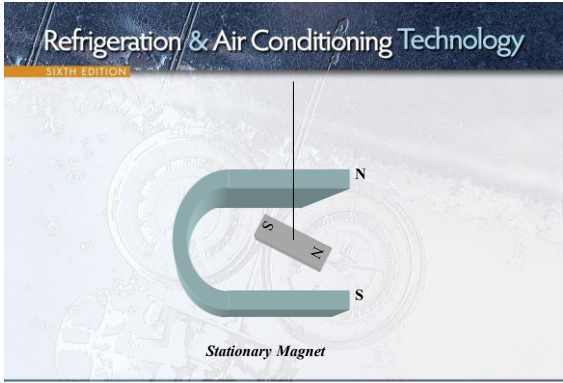


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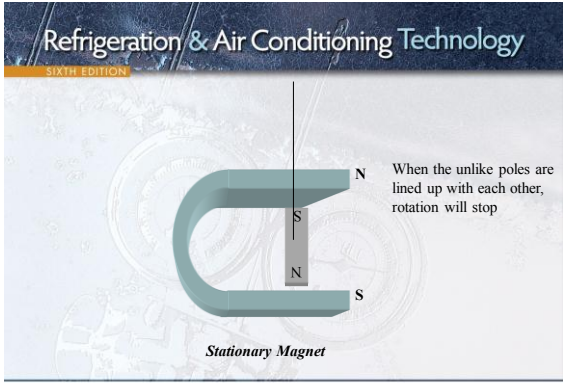




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DETERMINING MOTOR SPEED

- As the number of poles increases, the motor speed decreases
- Motor Speed (rpm) = Frequency x 120 ÷ # of poles
- In the United States the frequency is 60 Hz
- For example, a 2 pole motor will turn at a speed of $60 \times 120 \div 2 = 7200 \div 2 = 3600$ rpm
- The motor will turn at a speed that is lower than the calculated value
- Slip = difference between calculated and actual motor speed

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THE START WINDING

- Enables the motor to start and in the right direction
- Start winding has higher resistance than the run winding
- Wound with more turns than the run winding
- Wound with smaller diameter wire than the run winding
- Removed from the active circuit once the motor starts

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STARTING AND RUNNING CHARACTERISTICS

- Refrigeration compressors have high starting torque
- Starting torque – twisting force that starts the motor
- Locked Rotor Amperage (LRA)
- Full Load Amperage (FLA)
- Rated Load Amperage (RLA)
- Motor may start with unequal pressures across it
- Small fans do not require much starting torque

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ELECTRICAL POWER SUPPLIES

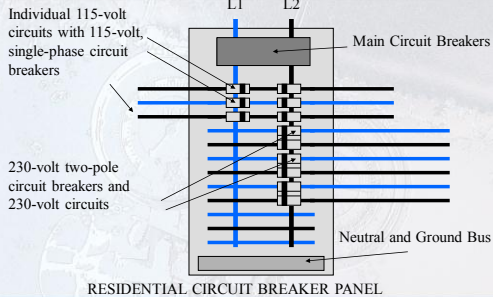
- Residences are furnished with single-phase power
- Houses can be supplied power from the transformer
- Power feeds into circuit breaker panel or fuse box
- Circuit breakers protect each individual circuit
- Power is distributed throughout the house
- Typical residential panels provide 115 and 230 volts
- Commercial and industrial facilities require three-phase power

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SINGLE-PHASE OPEN MOTORS

- Residential motors operate at 115, 208 or 230V
- Commercial motors operate at voltages up to 460V
- Some motors are designed to operate at one of two different voltage (dual voltage motors)
- Dual voltage motors are wired differently for each voltage
- Some motors have reversible rotations

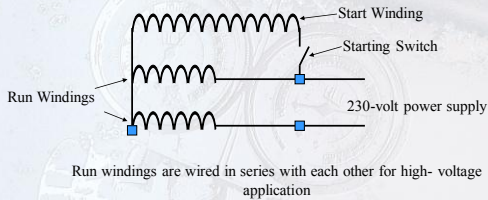
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DUAL VOLTAGE MOTOR (230-VOLTS)



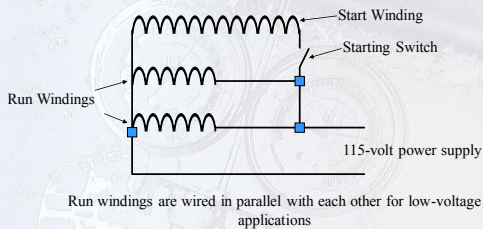
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DUAL VOLTAGE MOTOR (115-VOLTS)



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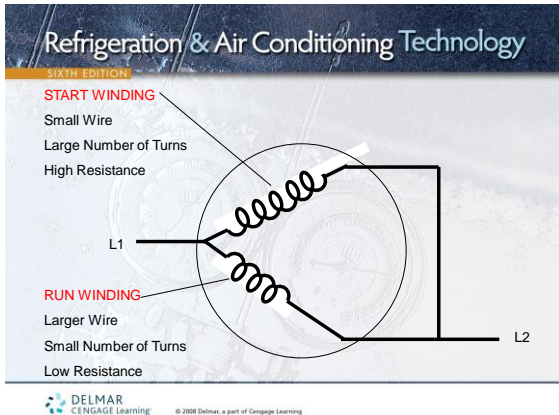
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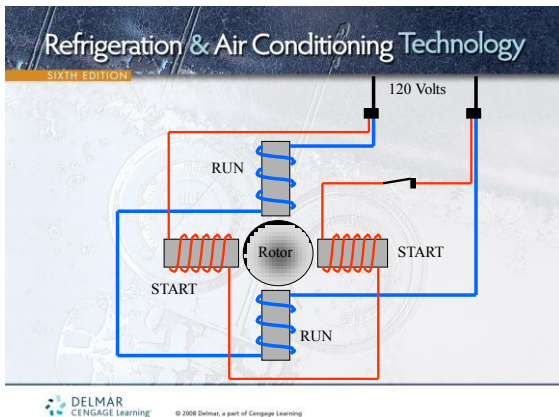
SPLIT-PHASE MOTORS

- Two separate motor windings
- Good running efficiency
- Medium amount of starting torque
- Speed typically ranges from 1800 – 3600 rpm
- Motor speed is determined by the number of poles
- Slip is the difference between the calculated and actual motor speeds

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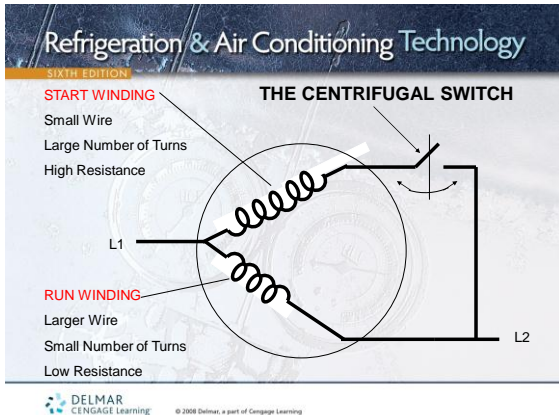
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THE CENTRIFUGAL SWITCH

- Commonly used on open motors to de-energize the start winding
- Opens its contacts when the motor reaches about 75% of its rated speed
- When the contacts open and close, a spark is created (arcing)
- Not used in a refrigerant atmosphere

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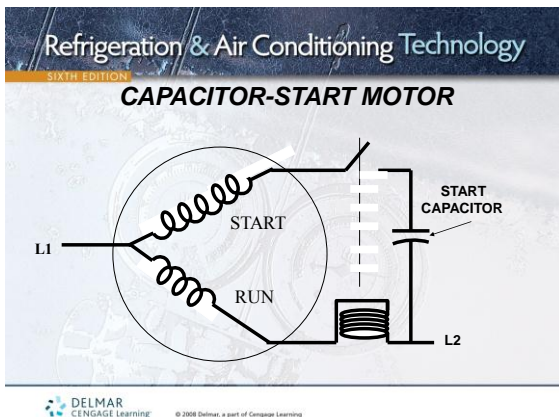


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CAPACITOR-START MOTOR

- Split phase motor with start and run windings
- Start capacitor assists the motor starting by increasing the starting torque
- Start capacitor is wired in series with the motor's start winding
- Start capacitor is removed from the circuit when the start winding is removed
- Start capacitor increases the phase angle

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PHASE ANGLE

- Number of electrical degrees between the current and the voltage
- In a resistive circuit the current and voltage are in phase with each other and the phase angle is zero
- The current can lead or lag the voltage
- In inductive circuits, the current lags the voltage
- In capacitive circuits, the current leads the voltage

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CAPACITOR-START, CAPACITOR-RUN MOTOR

- Most efficient single-phase motor
- Often used with belt-driven fans and blowers
- Run capacitor improves running efficiency
- Run capacitor is in the circuit whenever the motor is energized
- Start and run capacitors are wired in parallel
- Motor amperage will rise if run capacitor goes bad

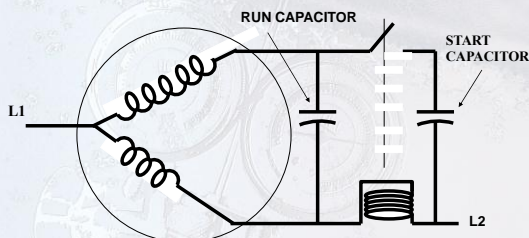
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CAPACITOR-START, CAPACITOR-RUN MOTOR (CSCR)


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PERMANENT SPLIT CAPACITOR (PSC) MOTOR

- Simplest split-phase motor
- Only a run capacitor is used
- Low starting torque and good running efficiency
- Can be single or multispeed motors
- Multispeed motors have leads for each speed
- As the resistance decreases, motor speed increases
- As the resistance increases, motor speed decreases

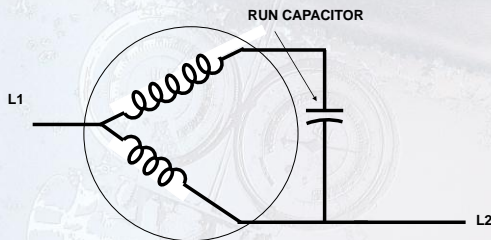
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PERMANENT SPLIT CAPACITOR MOTOR (PSC)



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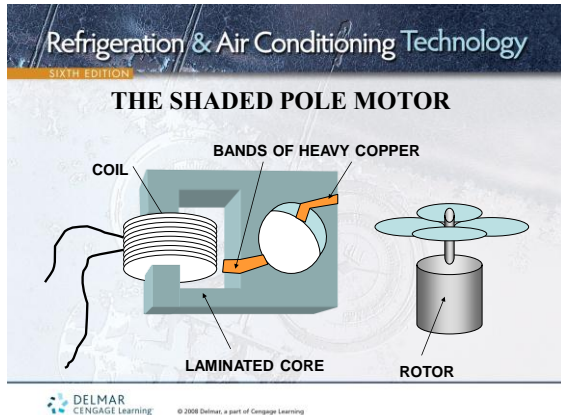
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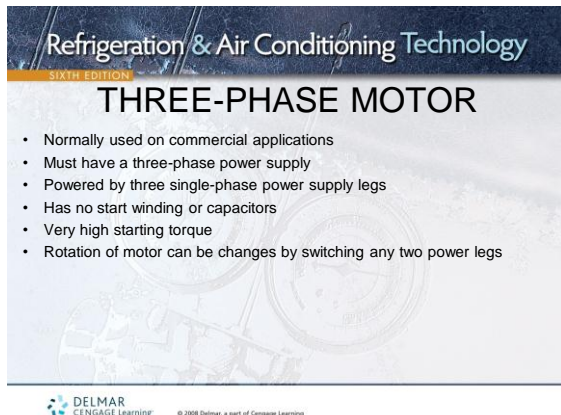
SHADED-POLE MOTOR

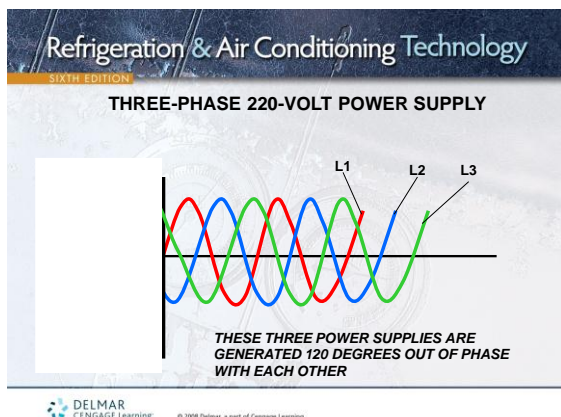
- Very low starting torque
- Not as efficient as the PSC motor
- A portion of the run winding is shaded to provide the imbalance in magnetic field that allows the motor to start
- Heavy copper wire or bands are used to shade the run winding
- Manufactured in the fractional horsepower range

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SINGLE-PHASE HERMETIC MOTORS

- Hermetically sealed from outside air
- Similar to single-phase motors
- Use relays to remove start winding from circuit
- They do not use centrifugal switches
- Often use run capacitors for increased efficiency
- Designed to operate in a refrigerant atmosphere
- Motor terminals identified as common, start & run

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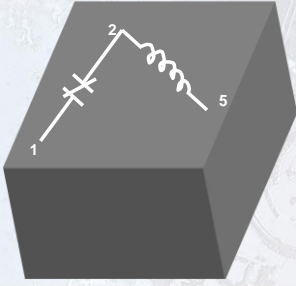
THE POTENTIAL RELAY

- Used on motors requiring high starting torque
- Coil with very high resistance
- Normally closed contacts
- Relay operates on the induced voltage across the start winding
- The contacts open when the induced voltage rises
- When the motor turns off, the induced voltage drops and the relay contacts close

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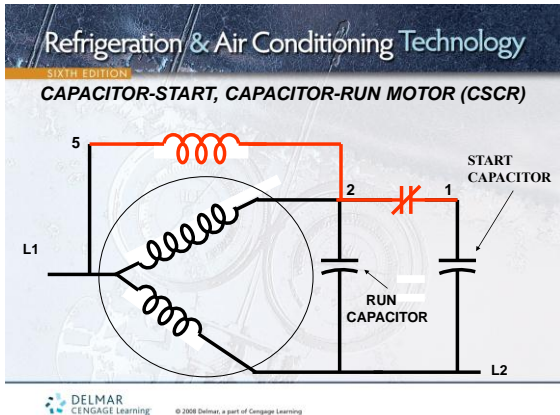
THE POTENTIAL RELAY



Normally close contacts connected between terminals 1 and 2

Coil connected between terminals 2 and 5

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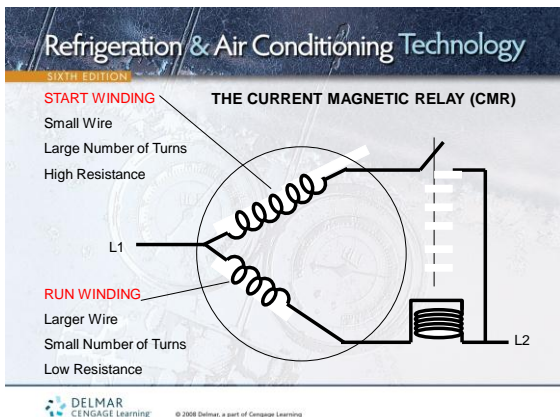
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THE CURRENT RELAY

- Used on fractional horsepower motors
- Used with fixed-orifice metering devices
- Low resistance coil in series with the run winding
- Normally open contacts in series with start winding
- Upon startup only the run winding is energized
- The motor draws locked rotor amperage
- The increased amperage closes the relay contacts
- The start winding is energized and the motor starts
- The amperage drops and the relay contacts open

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POSITIVE TEMPERATURE COEFFICIENT (PTC) START DEVICE

- Thermistors change resistance with changes in temperature
- During startup, the resistance of the PTC is about 4 to 10 ohms
- As the motor operates, current flow generates heat that causes the resistance to increase
- Resistance can increase to 10,000 to 12,000 ohms

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TWO-SPEED COMPRESSOR MOTORS

- Used to control the capacity of compressors
- Speed changes are obtained by wiring changes
- The thermostat controls the wiring changes
- Considered to be two compressors in one housing
- One motor turns at 1800 rpm, the other at 3600
- Two-speed compressors have more than three motor terminals

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SPECIAL APPLICATION MOTORS

- Some single-speed motors have more than three motor terminals
- Some have auxiliary compressor windings to increase the motor efficiency
- Some motors have winding thermostats wired through the compressor shell
- Three-phase motors have one thermostat for each winding
- The winding thermostats are wired in series

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THREE-PHASE COMPRESSOR MOTORS

- Used in large commercial/industrial applications
- Normally have three motor terminals
- No capacitors are required
- Resistance across each winding is the same
- Three-phase motors have high starting torque
- Some larger three-phase compressor motors operate as dual voltage device

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VARIABLE SPEED MOTORS

- Motor speed decreases during low load conditions
- Voltage and frequency determine motor speed
- New motors are controlled by electronic circuits
- Variable speed direct current (dc) motors
- Electronically commutated (ECM) dc motors
- Motors can ramp up or down to reduce motor wear
- AC current can be converted to DC using rectifiers

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DC CONVERTERS (RECTIFIERS)

- Phase-controlled rectifier
 - Converts ac power to dc power
 - Uses silicon controlled rectifiers and transistors
 - Capacitors smooth out the dc voltage
- Diode bridge rectifier
 - Does not regulate the dc voltage
 - Diodes are not controllable
 - Voltage and frequency are adjusted at the inverter

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INVERTERS

- Vary the frequency to obtain the desired speed
- Six-step inverter
 - Receives voltage from the converter
 - Can control the voltage or the current
- Pulse width modulator (PWM)
 - Receives fixed dc voltage from the converter
 - Voltage is pulsed to the motor
 - Short pulses at low speed, long pulses at high speed

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ELECTRONICALLY COMMUTATED MOTORS (ECM)

- Used on open drive fans less than 1 hp
- Armature is commutated with permanent magnets
- Motors are factory calibrated
- Two-piece motor: motor section and controls
- Motor can be checked with an ohmmeter
- Controls can be checked with a test module
- Defective controls can be replaced

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COOLING ELECTRIC MOTORS

- All motors must be cooled
- Hermetic compressor motor are cooled by air and refrigerant
- Open motors are cooled by air
- Open motors must be located where there is a good supply of air
- Some very large motors are cooled by water

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UNIT SUMMARY - 1

- Motors facilitate the circulation of air, water, refrigerant and other fluids
- Some applications require high starting torque
- Motor components include the housing, rotor, stator, end bells, bearings and motor mount
- Electricity and magnetism create motor rotation
- Motor speed is determined by the number of poles
- The start winding has higher resistance than the run winding
- Important motor amperage are LRA, FLA and RLA

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UNIT SUMMARY - 2

- Residences are supplied with single-phase power
- Some motors are designed to operate at more than one voltage
- Split phase motors have a medium amount of starting torque and good running efficiency
- The centrifugal switch opens and closes its contacts depending on the speed of the motor
- The current relay opens and closes its contacts depending on the current flow through the run winding

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UNIT SUMMARY - 3

- The potential relay opens and closes its contacts depending on the induced voltage across the start winding
- Capacitor start motors use start capacitors to increase the starting torque of the motor
- The start winding and start capacitor are removed from the circuit after the motor starts
- Capacitor start, capacitor run motors use both start and run capacitors
- Run capacitors help increase the motor's running efficiency

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UNIT SUMMARY - 4

- The PSC motor uses only a run capacitor
- The shaded pole motor has very low starting torque
- Three-phase motors are used for commercial and industrial applications
- The PTC and NTC are electronic device that change their resistance as the sensed temperature changes
- Variable speed motors ramp up and down, often using dc converters, inverters and rectifiers
- ECM motors are commutate with permanent magnets

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