Refrigeration & Air Conditioning Technology

SIXTH EDITION

SECTION 5

COMMERCIAL REFRIGERATION

UNIT 23

COMPRESSORS

DELMAR CENGAGE Learning

UNIT OBJECTIVES

After studying this unit, the reader should be able to

- Explain the function of the compressor in a refrigeration system.
- Discuss compression ratio.
- Describe four different methods of compression.
- State specific conditions under which a compressor is expected to operate.
- Explain the difference between a hermetic compressor and a semi-hermetic compressor.
- Describe the various working parts of reciprocating and rotary compressors.

FUNCTION OF THE COMPRESSOR

- Considered the heart of the refrigeration systems
- Compressors are vapor pumps
- Responsible for lowering the pressure on the suction side of the system
- Responsible for increasing the pressure on the discharge side of the system
- Suction gas from the evaporator enters the compressor
- Refrigerant is discharged to the condenser

COMPRESSION RATIO

- Compares pumping conditions for compressors
- Defined as the high side pressure (psia) divided by the low side pressure (psia)
- High compression ratio can lead to overheated compressor oil
- High compression ratio leads to reduced refrigerant flow through the system
- Reduced refrigerant flow reduces system capacity

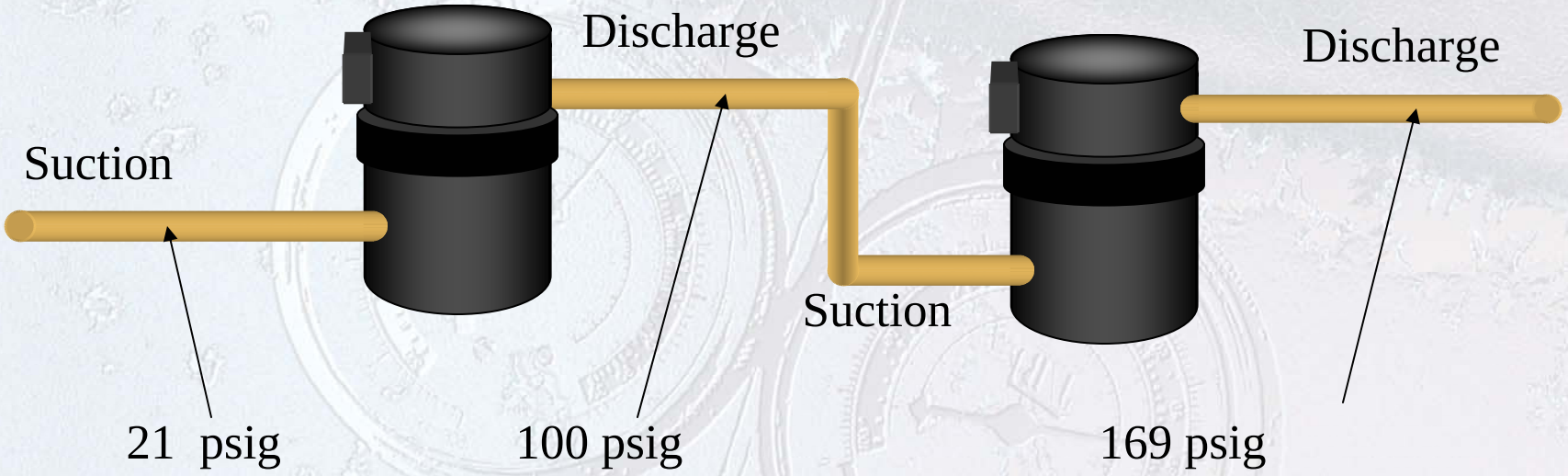
COMPRESSION RATIO EXAMPLES

- R-12 compressor
  - 169 psig high side, 2 psig low side
  - 183.7 psia high side, 16.7 psia low side
  - 183.7 psia ÷ 16.7 psia = **11:1 compression ratio**
- R-134a compressor
  - 184.6 psig high side, 0.7 in. Hg. vacuum low side
  - 199.3 psia high side, 14.35 psia low side
  - 199.3 psia ÷ 14.35 psia = **13.89:1 compression ratio**

TWO-STAGE COMPRESSION

- Lowers the compression ratio
- Utilizes two compressors
- One compressor discharges into suction of the other
- Also referred to as compound compression
- Often used when the compression ratio of a single compressor system exceeds 10:1
- Often used in low-temperature commercial and industrial storage applications

TWO-STAGE COMPRESSION



FIRST STAGE SECOND STAGE

TYPES OF COMPRESSORS

- Reciprocating
  - Fully welded, hermetic compressors
  - Semi-hermetic compressors
  - Open-drive compressors
  - Belt-driven and direct-drive compressors
- Screw compressors
- Rotary compressors
- Scroll compressors
- Centrifugal compressors

WELDED HERMETIC RECIPROCATING COMPRESSORS

- Motor and compressor contained in a welded shell
- Cannot be field serviced
- Typically a “throw-away” compressor
- Considered to be a low-side component
- Cooled by suction gas from the evaporator
- Lubricated by the splash method

SEMI-HERMETIC COMPRESSORS

- Bolted together, can be field serviced
- Housing is made of cast iron
- Has a horizontal crankshaft
- Smaller compressors are splash lubricated
- Larger compressors use pressure lubrication systems
- Often air cooled
- Piston heads are located at the top of the compressor

OPEN DRIVE COMPRESSORS

- Can be direct drive or belt-driven compressors
- Must have a shaft seal to prevent leakage
- Bolted together, can be filed serviced
- Belt-driven compressors have the compressor and motor shafts parallel to each other
- Belt-driven compressors use belts and pulleys
- Direct drive compressors have the compressor and motor shafts connected end to end

OTHER COMPRESSOR TYPES

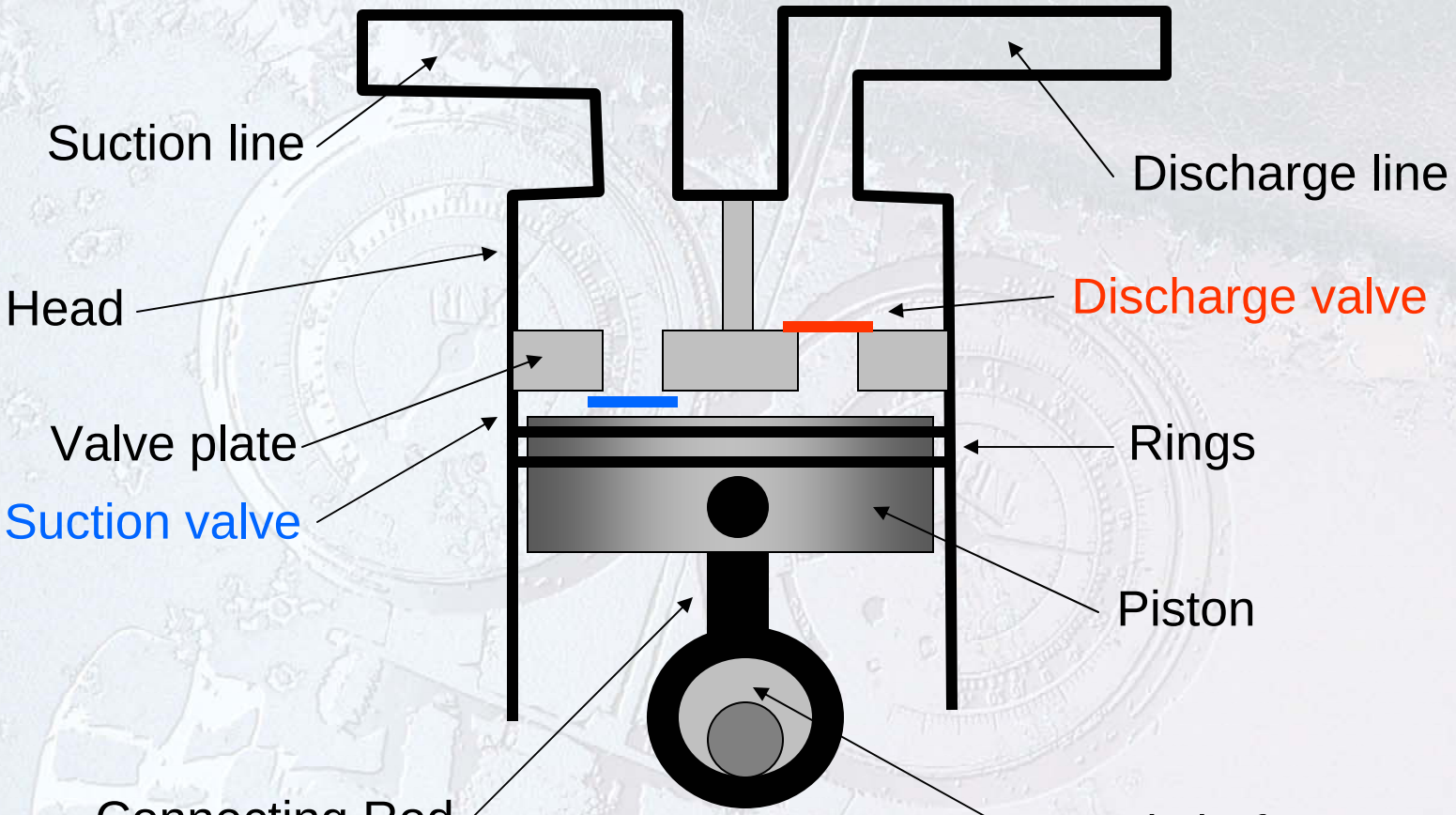
- Screw compressor
  - Used in large commercial/industrial applications
  - Uses two matching, tapered gears, and open motor design
- Rotary compressor
  - Used in residential and light commercial applications
- Scroll compressor
  - Uses a matched set or scrolls to achieve compression
- Centrifugal compressors
  - Used extensively for air conditioning in large structures

RECIPROCATING COMPRESSOR COMPONENTS

- Crankshaft
  - Transfers motor motion to the piston
  - Creates the back and forth motion of the piston
- Connecting rods
  - Connects the crankshaft to the pistons
- Pistons
  - Slide up and down in the cylinder
  - Used to compress and expand the refrigerant

RECIPROCATING COMPRESSOR COMPONENTS (cont'd)

- Refrigerant cylinder valves (suction)
  - Durable, flexible steel
  - Located on the bottom of the valve plate
  - Open when refrigerant is introduced to the pump
- Refrigerant cylinder valves (discharge)
  - Durable, flexible steel
  - Open when refrigerant is discharged from the pump
  - Located on the top of the valve plate



RECIPROCATING COMPRESSOR COMPONENTS (cont'd)

- Compressor head
  - Holds the top of the cylinder and its components together
  - Contains both high and low pressure refrigerant
- Mufflers
  - Designed to reduce compressor noise
- Compressor housing
  - Encases the compressor and sometimes the motor

BELT-DRIVE MECHANISMS

- Motor pulley is called the drive pulley
- Compressor pulley is called the driven pulley
- Pulleys can be adjusted to change compressor speed
- Drive size x Drive rpm = Driven size x Driven rpm
- Shafts must be properly aligned
- Pulleys with multiple grooves must used matched sets of belts

DIRECT-DRIVE COMPRESSOR CHARACTERISTICS

- Direct drive compressors turn at the same speed as the motor used
- Motor shaft and compressor shaft must be perfectly aligned end to end
- Motor shaft and compressor shafts are joined with a flexible coupling

RECIPROCATING COMPRESSOR EFFICIENCY

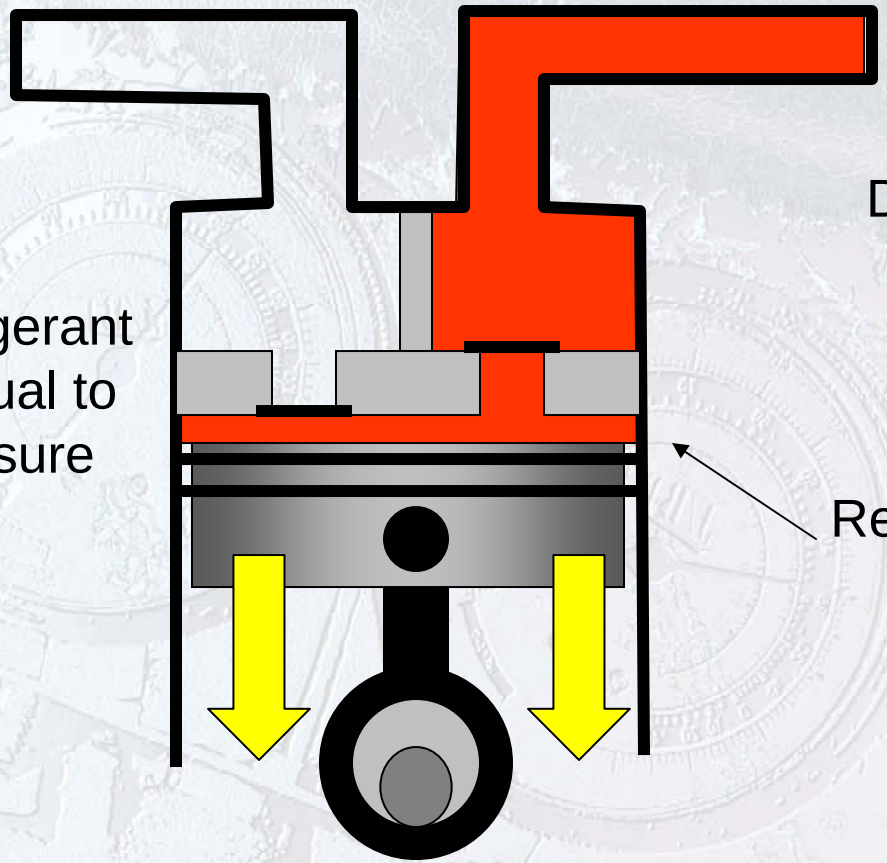
- Determined by initial compressor design
- Four processes take place during the compression process
  - Expansion (re-expansion)
  - Suction (Intake)
  - Compression
  - Discharge

COMPRESSION PROCESS - EXPANSION

- Piston is the highest point in the cylinder
- Referred to as top dead center
- Both the suction and discharge valves are closed
- Cylinder pressure is equal to discharge pressure
- As the crankshaft continues to turn, the piston moves down in the cylinder
- The volume in the cylinder increases
- The pressure of the refrigerant decreases

Suction valve closed

Pressure of the refrigerant in the cylinder is equal to the discharge pressure



Discharge valve closed

Refrigerant trapped in the cylinder

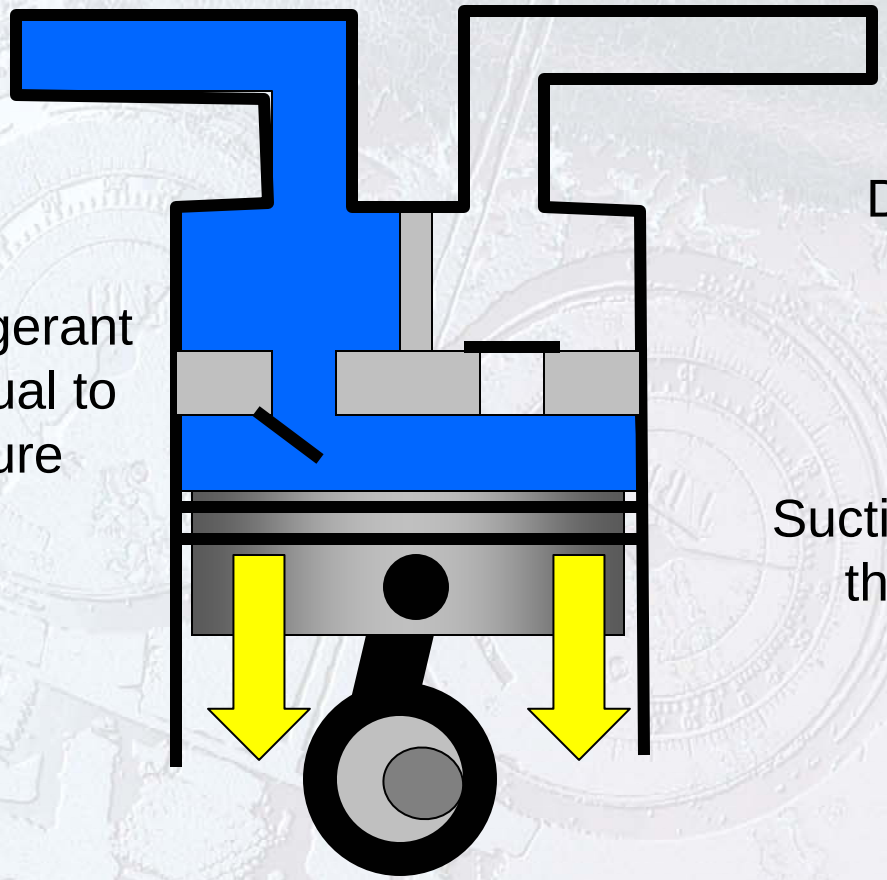
Piston moving downward in the cylinder

COMPRESSION PROCESS – SUCTION

- As the piston moves down, the pressure decreases
- When the cylinder pressure falls below suction pressure, the suction valve opens
- The discharge valve remains in the closed position
- As the piston continues downward, vapor from the suction line is pulled into the cylinder
- Suction continues until the piston reaches the lowest position in the cylinder (bottom dead center)
- At the bottom of the stroke, suction valves close

Suction valve open

Pressure of the refrigerant in the cylinder is equal to the suction pressure



Discharge valve closed

Suction gas pulled into the compression cylinder

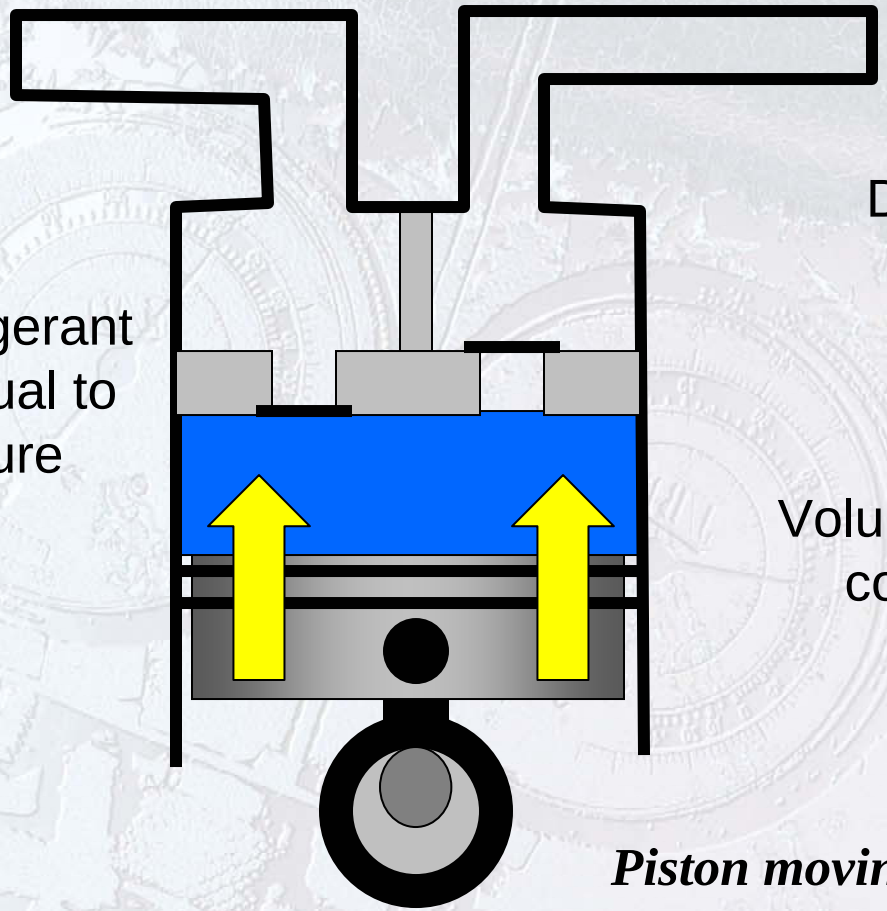
Piston moving downward in the cylinder

COMPRESSION PROCESS - COMPRESSION

- Piston starts to move upwards in the cylinder
- The suction valve closes and the discharge valve remains closed
- As the piston moves upwards, the volume in the cylinder decreases
- The pressure of the refrigerant increases
- Compression continues until the pressure in the cylinder rises just above discharge pressure

Suction valve closed

Pressure of the refrigerant in the cylinder is equal to the suction pressure



Discharge valve closed

Volume is decreasing, compressing the refrigerant

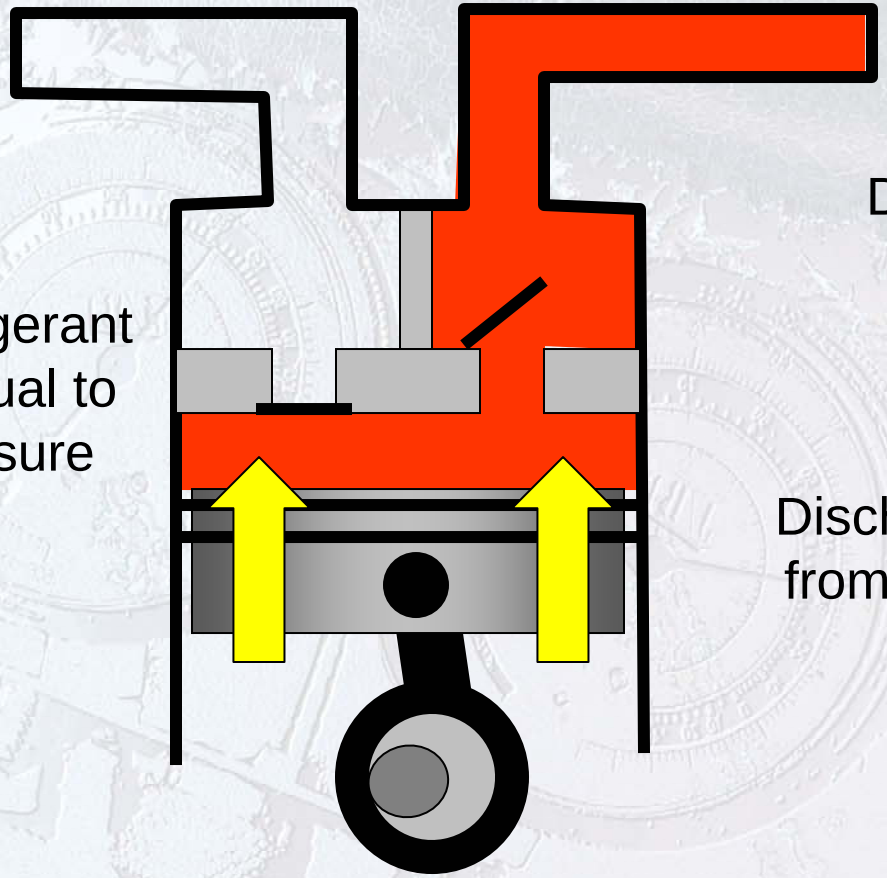
Piston moving up in the cylinder

COMPRESSION PROCESS - DISCHARGE

- When the cylinder pressure rises above discharge pressure, the discharge valve opens and the suction valve remains closed
- As the piston continues to move upwards, the refrigerant is discharged from the compressor
- Discharge continues until the piston reaches top dead center

Suction valve open

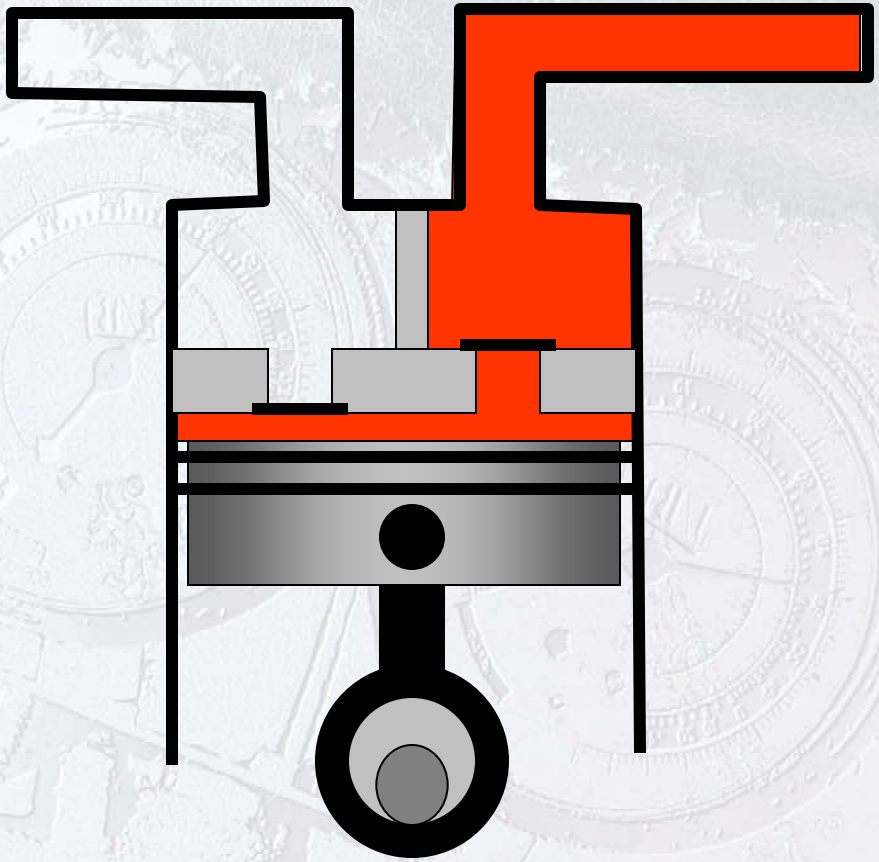
Pressure of the refrigerant in the cylinder is equal to the discharge pressure

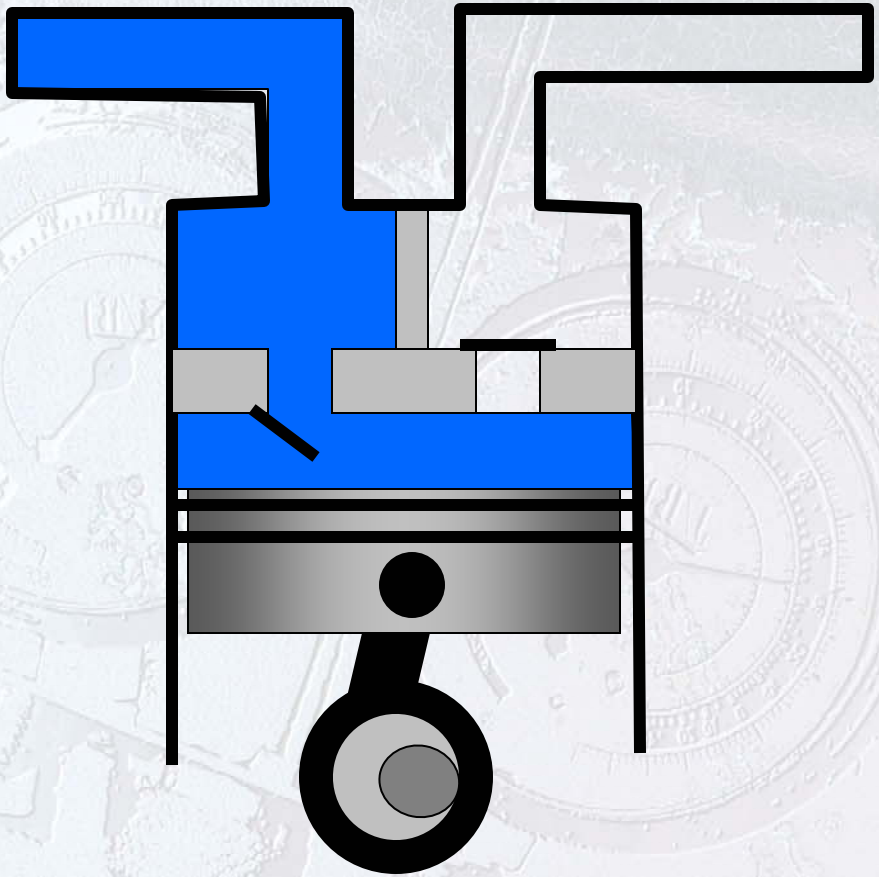


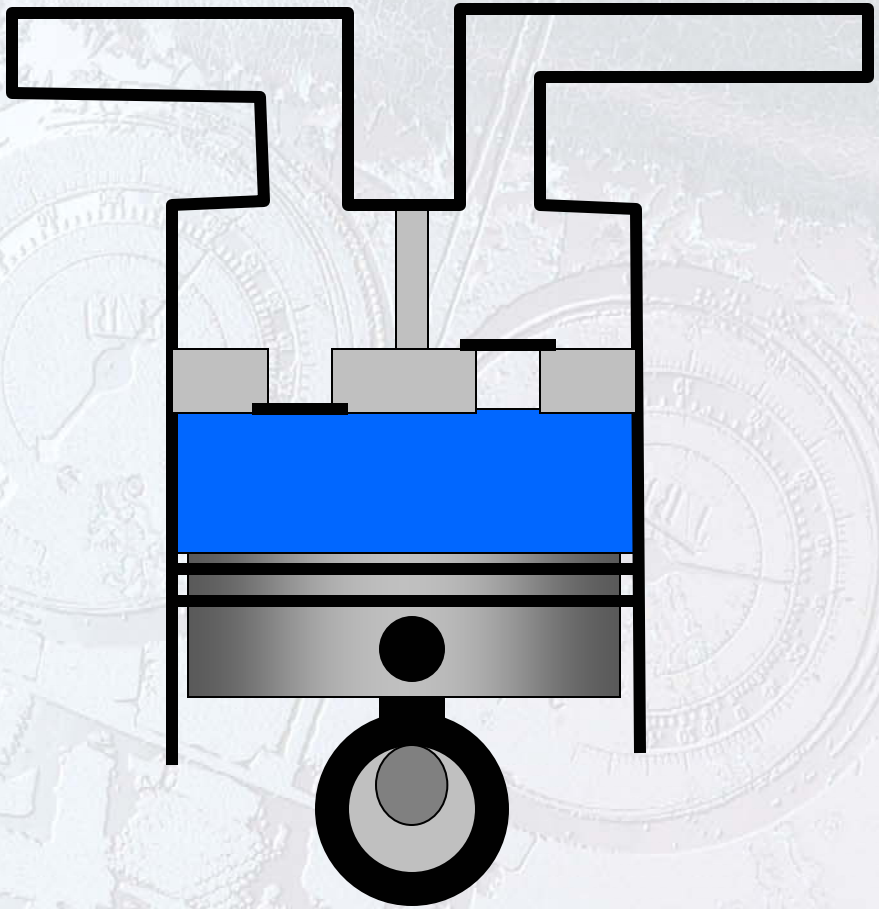
Discharge valve closed

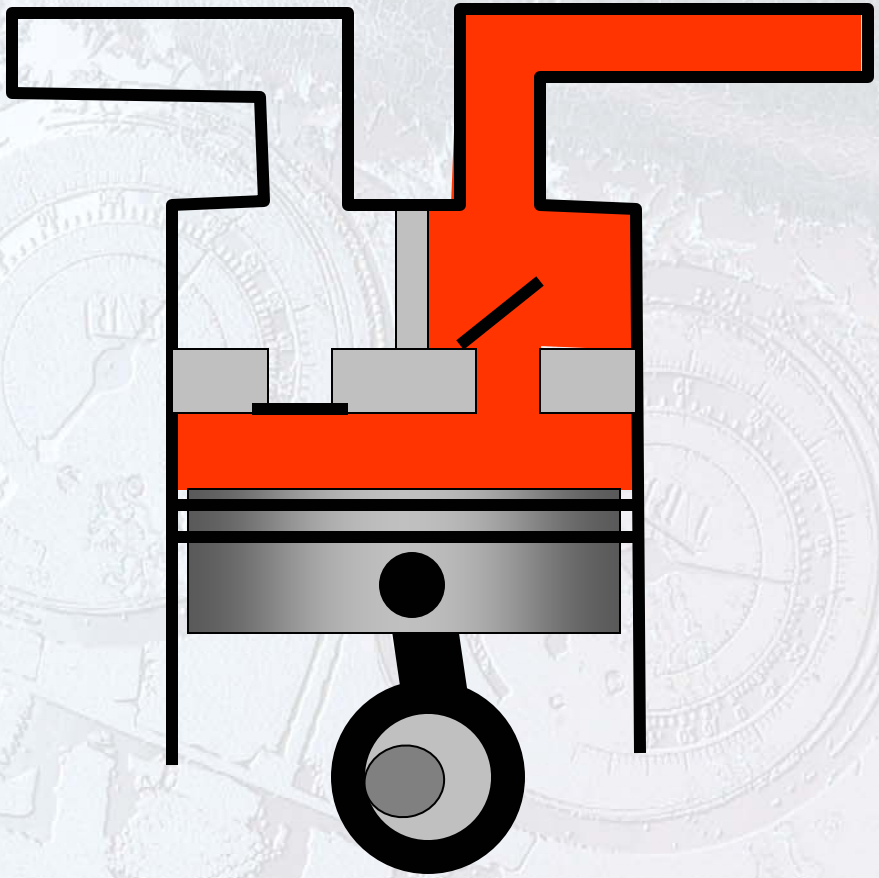
Discharge gas pushed from the compression cylinder

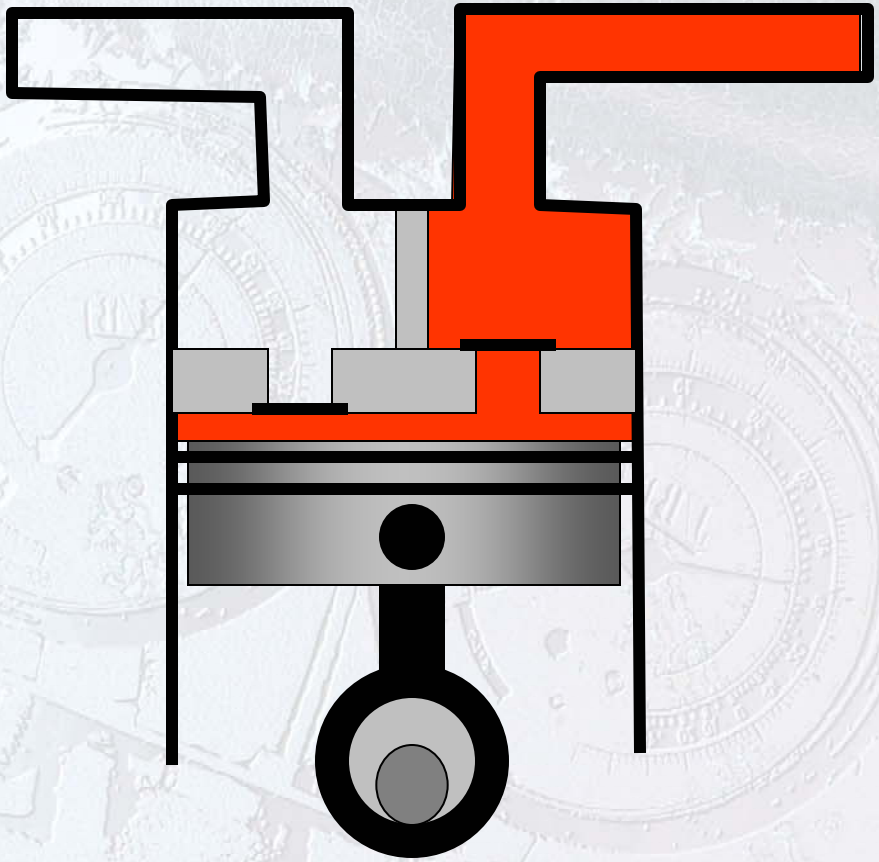
Piston moving up in the cylinder

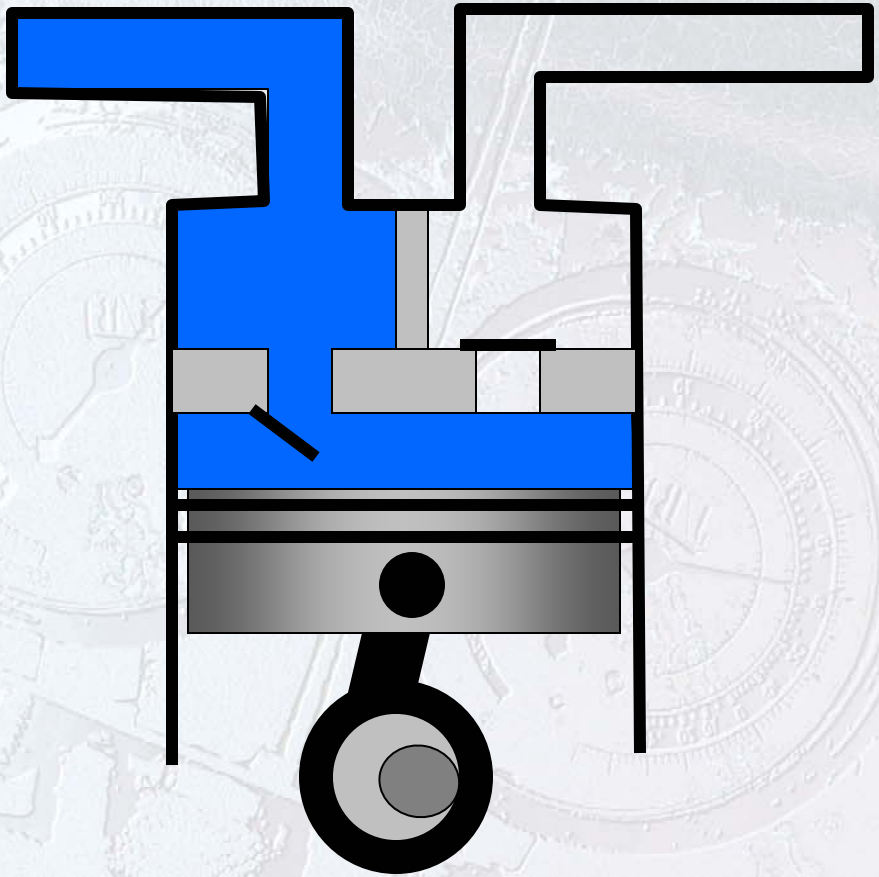


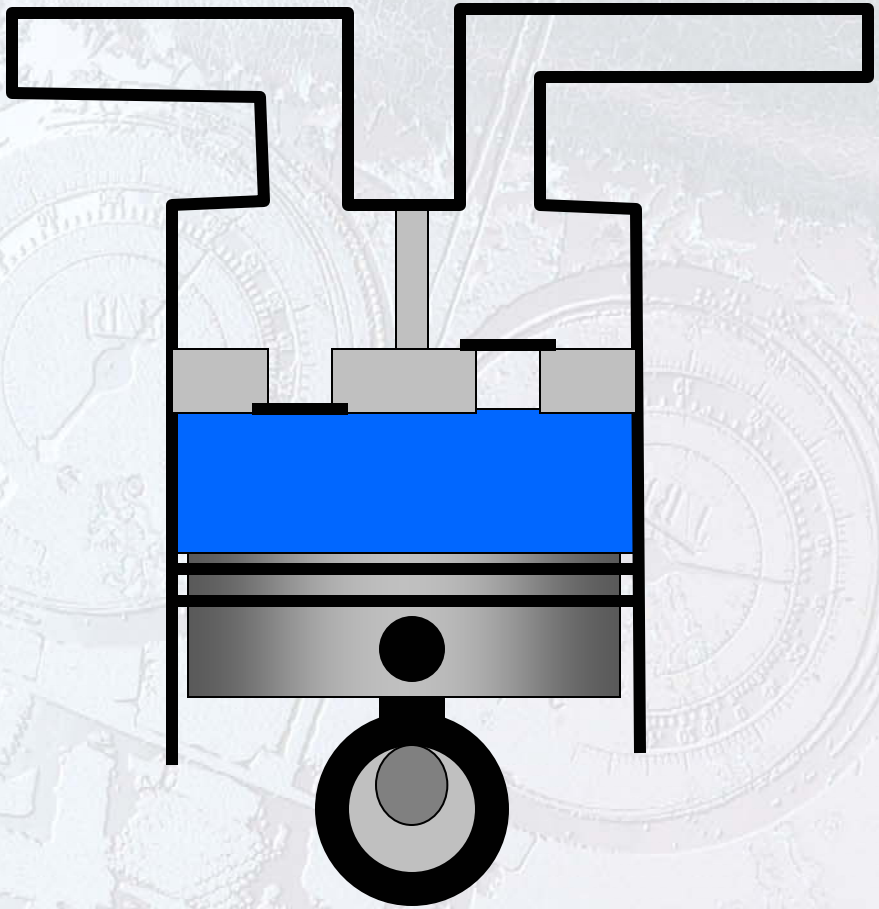


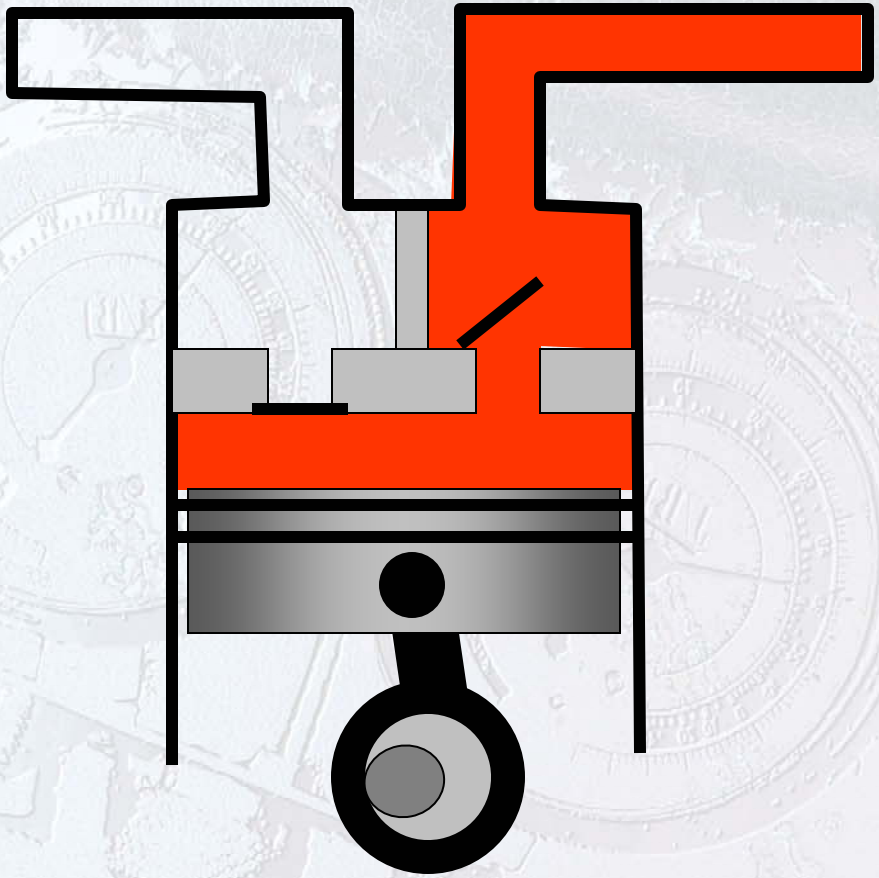












LIQUID IN THE COMPRESSION CYLINDER

- If liquid enters the cylinder, damage will occur
- Liquids cannot be compressed
- Liquid slugging can cause immediate damage to the compressor components
- Common causes of liquid slugging include an overfeeding metering device, poor evaporator air circulation, low heat load, defective evaporator fan motor and a frosted evaporator coil

SYSTEM MAINTENANCE AND COMPRESSOR EFFICIENCY

- High suction pressures and low discharge pressures keep the compression ratio low
- Dirty evaporators cause suction pressure to drop
- Low suction reduces compressor pumping capacity
- Dirty condensers increase head pressure
- Compression ratio is increased by dirty or blocked condenser and evaporator coils

UNIT SUMMARY - 1

- The compressor is responsible for pumping refrigerant through the refrigeration system
- The compressor lowers the pressure on the low side of the system and increases the pressure on the high side of the system
- The compression ratio compares pumping conditions for compressors
- Comp. Ratio = High side (psia) ÷ Low side (psia)

UNIT SUMMARY - 2

- Two-stage compression uses two compressors where one compressor discharges into the suction of the second compressor
- Used when the compression ratio for single-stage compression is higher than 10:1
- Common compressor types include the rotary, the reciprocating, the scroll, the screw and the centrifugal

UNIT SUMMARY - 3

- Hermetic compressors are factory welded and not field serviceable
- Semi-hermetic compressors are bolted together and can be serviced in the field
- Open drive compressors have the motor separate from the compressor
- Open drive compressors can be direct drive or belt-driven

UNIT SUMMARY - 4

- Reciprocating compressors are equipped with suction and discharge valves
- The suction and discharge valves open and close to facilitate the expansion, suction, compression and discharge processes
- Compressors can become damaged if liquid enters
- High suction pressures and low discharge pressures will help keep the compression ratio low