Refrigeration & Air Conditioning Technology
SIXTH EDITION

SECTION 5

COMMERCIAL REFRIGERATION

UNIT 22

CONDENSERS

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UNIT OBJECTIVES

After studying this unit, the reader should be able to

- explain the purpose of the condenser in a refrigeration system.
- describe differences between the operating characteristics of water-cooled and air-cooled systems.
- describe the basis of the heat exchange in a condenser.
- explain the difference between a tube-within-a-tube coil-type condenser and a tube-within-a-tube serviceable condenser.
- describe the difference between a shell-and-coil condenser and a shell-and-tube condenser.
- values.

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UNIT OBJECTIVES

After studying this unit, the reader should be able to

- describe a wastewater system.
- describe a recirculated water system.
- describe a cooling tower.
- explain the relationship between the condensing refrigerant and the condensing medium for cooling tower systems.
- compare an air-cooled, high-efficiency condenser with a standard condenser.
- describe the operation of head pressure control values.

THE CONDENSER

- Heat exchange surface that rejects system heat
- Rejects sensible heat
  - Desuperheating vapor refrigerant from the compressor
  - Subcools refrigerant at the outlet of the condenser
- Rejects latent heat during the condensing process
- The greatest amount of heat is transferred during the change of state
- Condenser is on the high pressure side of the system

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WATER-COOLED CONDENSERS

- More efficient than air-cooled condensers
- Water temperature can be maintained
- Water temperature directly affects system pressures
- Three types of water-cooled condensers
  - Tube within a tube condenser
  - Shell and coil condenser
  - Shell and tube condenser

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TUBE WITHIN A TUBE CONDENSER

- Heat exchange takes place between the fluids in the inner and outer tubes
- Refrigerant flows in the outer tube
- Water flows in the inner tube
- Refrigerant and water flow in opposite directions to maximize the heat transfer rate
- Depending on the construction, the condenser can be cleaned mechanically or chemically

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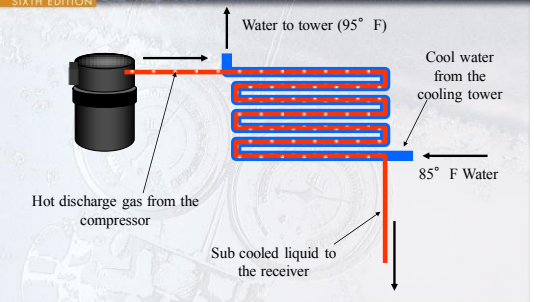

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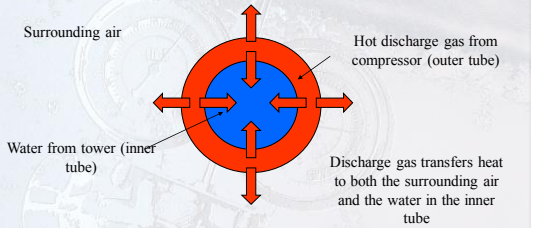
Cross-Section of a tube within a tube condenser



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MINERAL DEPOSITS

- Heat from the discharge gas causes minerals in the water to come out of solution
- These minerals form scale that adhered to the pipes
- The scale acts as an insulator and reduces the rate of heat transfer between the refrigerant and the water
- Water is chemically treated to reduce the rate of scale formation on the interior pipe surfaces
- Dirty condensers lead to high head pressures

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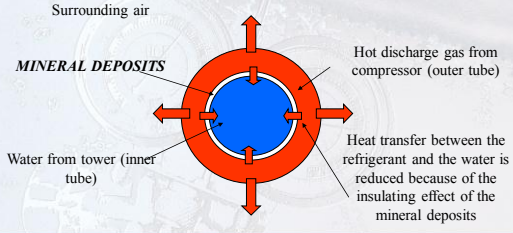
Cross-Section of a tube within a tube condenser



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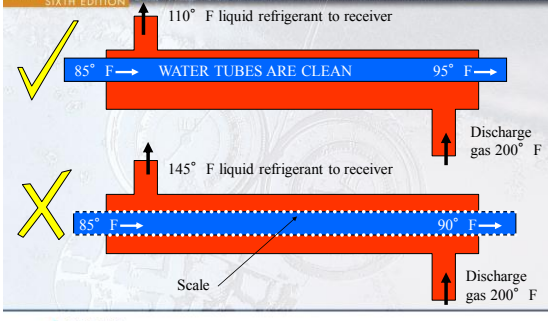

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MECHANICALLY CLEANABLE CONDENSERS

- Tube within a tube condenser has end flanges
- Flanges are removed to access the water circuit
- The refrigerant circuit remains sealed while the water circuit is open
- The mechanically cleanable tube-in-tube condenser is more costly than the chemically cleanable version of the condenser

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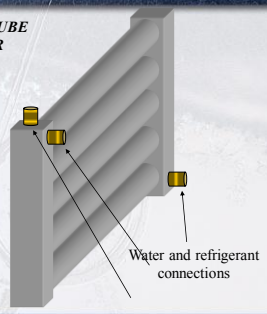
MECHANICALLY CLEANABLE TUBE WITHIN A TUBE CONDENSER



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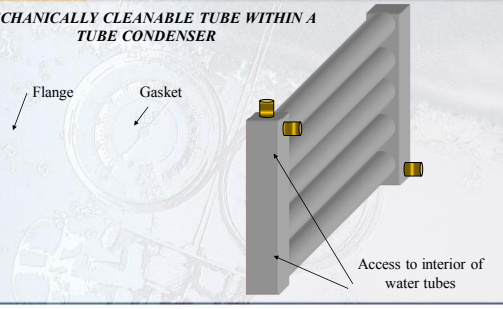
MECHANICALLY CLEANABLE TUBE WITHIN A TUBE CONDENSER



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SHELL AND COIL CONDENSERS

- Coil of tubing enclosed in a welded shell
- Water flows through the coil
- Refrigerant from the compressor is discharged into the shell
- The shell also acts as the receiver
- When refrigerant comes in contact with the cool coil, it condenses and falls to the bottom
- This condenser must be cleaned chemically

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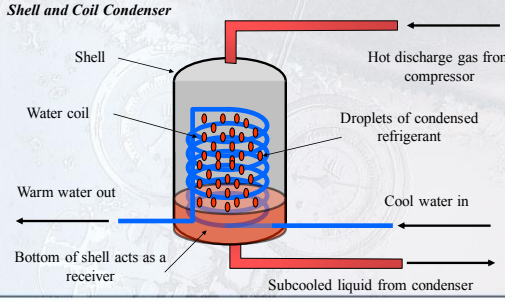
Shell and Coil Condenser



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SHEL AND TUBE CONDENSERS

- Can be cleaned mechanically
- Compressor discharge gas is piped into the shell
- Water flows through the tubes in the condenser
- The ends of the shell are removed for cleaning
- The shell acts as a receiver
- Refrigerant circuit is not disturbed when the ends of the shell (water boxes) are opened
- Most expensive type of condenser

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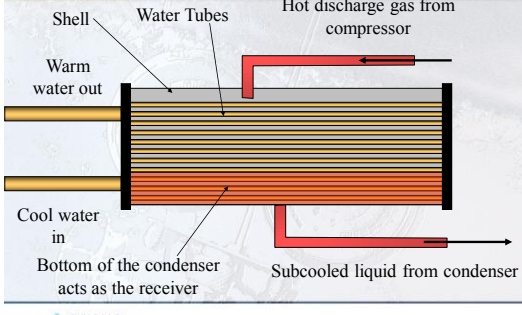

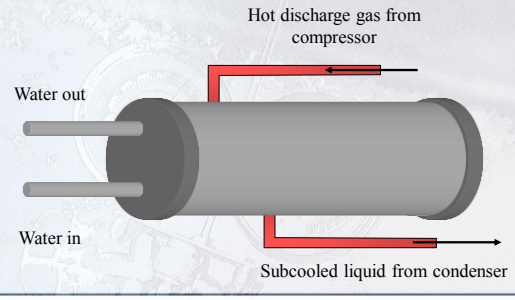

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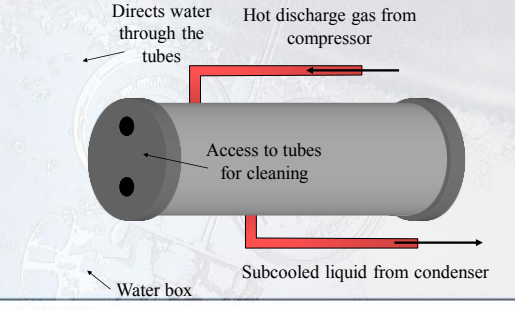

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WASTEWATER SYSTEMS

- Water used once and then "wasted" down the drain
- Economical if water is free or if the system is small
- The main drawback is that the water temperature can vary a great deal
- Typical water temperature is about 75° F
- 75° F wastewater requires a flow of about 1.5 gpm per ton of refrigeration to absorb the heat rejected by the condenser
- Water typically leaves the condenser at 95° F

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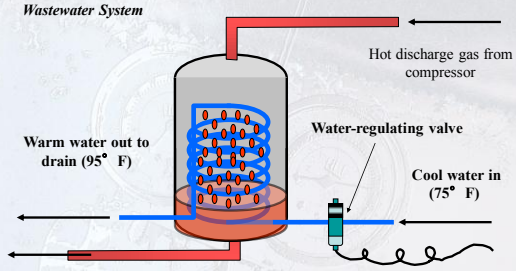
Wastewater System



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REFRIGERANT-TO-WATER TEMPERATURE RELATIONSHIP FOR WASTEWATER SYSTEMS

- Water flow is controlled by a water regulating valve
- Two pressures control the water regulating valve
  - The head pressure pushes to open the valve
  - The spring pressure pushes to close the valve
- The valve opens when the head pressure rises
- Water temperature is higher in the warmer months
- Water temperature is lower in the cooler months

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RECIRCULATED WATER SYSTEMS

- The water flowing through the condenser is pumped to a remote location, cooled and reused
- Design water temperature is 85° F
- A water flow rate of 3.0 gpm per ton of refrigeration is required to absorb the heat rejected by the system condenser
- The water leaving the condenser is about 95° F
- There is a 10 degree split across the water circuit

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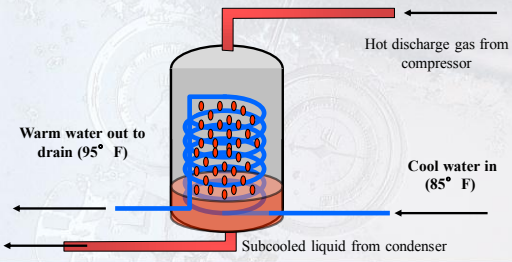
Recirculated Water System



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COOLING TOWERS

- Device used to remove heat from the water used in recirculated water systems
- Towers can cool the water to a temperature within 7° F of the wet bulb temperature of the air surrounding the tower
- If the wet bulb temperature is 90 degrees, water can be cooled to a temperature as low as 83° F
- Natural draft, forced draft, or evaporative

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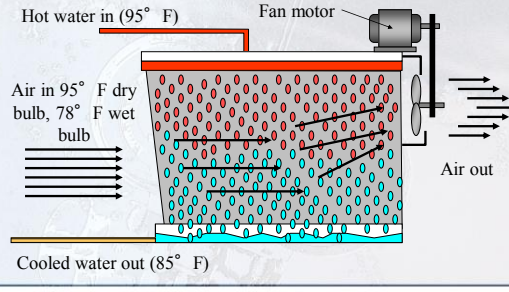

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NATURAL DRAFT COOLING TOWERS

- Redwood, fiberglass or galvanized sheet metal
- There are no blowers to move air through the tower
- Natural breezes move air through the tower
- Water enters the tower from the top and is cooled as the water falls to the bottom
- Some water evaporates in the process, helping to cool the remaining water in the tower
- Additional water is added through a float valve

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FORCED OR INDUCED DRAFT TOWERS

- Use a fan or blower to move air through the tower
- As the water falls through the tower, air is moved across it to aid in the cooling process
- Can be located almost anywhere
- The fan is cycled on and off to maintain the desired water temperature
- Forced draft – Air is pushed through the tower
- Induced draft – Air is pulled through the tower

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EVAPORATIVE CONDENSERS

- Designed to operate full of liquid
- A latent heat transfer takes place throughout the coil
- Coil efficiency is maximized
- Other devices must be used to prevent liquid from entering the compressor
- Normally use a float-type metering device to keep the liquid level in the coil high

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AIR-COOLED CONDENSERS

- Uses air to absorb heat rejected by the system
- Used in locations where water is difficult to use
- Horizontal, vertical, or side intake and top discharge
- Hot gas enters the condenser from the top
- For standard efficiency systems, the refrigerant will condense at a temperature about 30° F higher than the outside ambient temperature

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AIR-COOLED CONDENSER EXAMPLE

- R-134a medium temperature refrigeration system
- Outside air temperature 95° F
- Condensing temperature 125° F (95° F + 30° F)
- From P/T chart, high side pressure is 184 psig
- Discharge refrigerant from the compressor at 200° F
- Refrigerant must desuperheat from 200° F to 125° F
- Refrigerant will begin to condense at 125° F
- Liquid refrigerant subcools below 125° F

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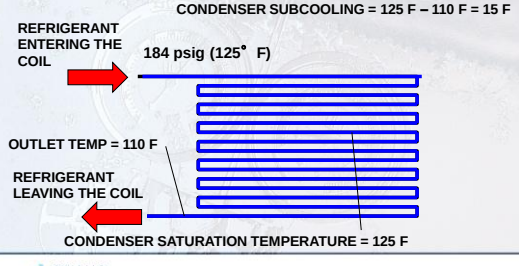
CALCULATING SUBCOOLING

Refrigerant R-134a



HIGH-EFFICIENCY CONDENSERS

- Have larger surface areas than standard condensers
- Allow systems to operate at lower pressures
- Allow systems to operate more efficiently
- Can operate with head pressures as low as 10° F higher than the outside ambient temperature

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THE CONDENSER AND LOW-AMBIENT CONTROLS

- Condensing temperatures drop when the outside ambient temperature drops
- The condensing pressure must be at least 75 psig higher than the evaporator pressure in order for the metering device to operate properly
- Low ambient controls
  - Designed to maintain the desired head pressure
  - Needed on systems that operate year-round

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HEAD PRESSURE CONTROL – FAN CYCLING DEVICES

- Used on air-cooled condensers
- As the head pressure drops, the fan cycles off
- As the head pressure rises, the fan cycles on
- Some condensers have more than one fan
  - Some fans remain on all the time
  - Others cycle on and off to maintain proper pressure
  - Can be controlled by pressure or temperature

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HEAD PRESSURE CONTROL – VARIABLE SPEED MOTORS

- Motor speed changes to maintain head pressure
- As the head pressure drops, the fan slows down
- As the head pressure rises, the fan speeds up
- Can utilize variable frequency drives (VFD)
- Maintains a more constant head pressure
- Can be controlled by pressure or temperature

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HEAD PRESSURE CONTROL – AIR SHUTTERS OR DAMPERS

- Located at the inlet or outlet of the condenser
- Opens and closes by a pressure-controlled piston
- Controls airflow through the condenser coil
- As ambient temperature drops, the dampers close to reduce the amount of airflow through the coil
- As ambient temperature rises, the dampers open to increase the amount of airflow through the coil

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HEAD PRESSURE CONTROL – CONDENSER FLOODING

- Valve installed in parallel with the condenser
- Valve closed when the ambient temperature is high
- Valve opens as the ambient temperature drops
- As the valve opens, refrigerant backs up in the condenser, reducing the heat transfer surface area
- During very cold weather, the condenser will be almost completely filled with liquid refrigerant
- Systems must have an oversized receiver

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FLOATING HEAD PRESSURES

- Term used for attaining the lowest possible condensing temperature in the system
- Allows the head pressure to follow the ambient temperature without using head pressure controls
- Newer expansion devices can operate properly with pressure differences as low as 30 psig
- Systems become more efficient since they operate at lower pressures

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UNIT SUMMARY - 1

- The condenser is the system component responsible for rejecting system heat
- Condensers reject both latent and sensible heat
- Water-cooled condensers are more efficient than air-cooled condensers
- Three types of water-cooled condensers are the tube within a tube, shell and coil, and the shell and tube
- Mineral deposits in the water circuit reduce the heat transfer rate between the water and the refrigerant

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UNIT SUMMARY - 2

- Some condensers can be mechanically cleaned while others must be cleaned chemically
- Wastewater systems use water once and then waste it down the drain
- Wastewater systems typically supply 75-degree water to the condenser and require 1.5 gpm/ton
- Recirculating water systems typically supply 85-degree water and require 3.0 gpm/ton

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UNIT SUMMARY - 3

- Wastewater systems utilize a water-regulating valve while recirculated water systems do not
- Evaporative condensers use a combination of water and air to achieve the condensing process
- High efficiency condensers operate with lower head pressures than standard efficiency condensers
- Low ambient controls allow systems to operate properly when the ambient temperature is low