SECTION 5

COMMERCIAL REFRIGERATION

UNIT 22

CONDENSERS

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.

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

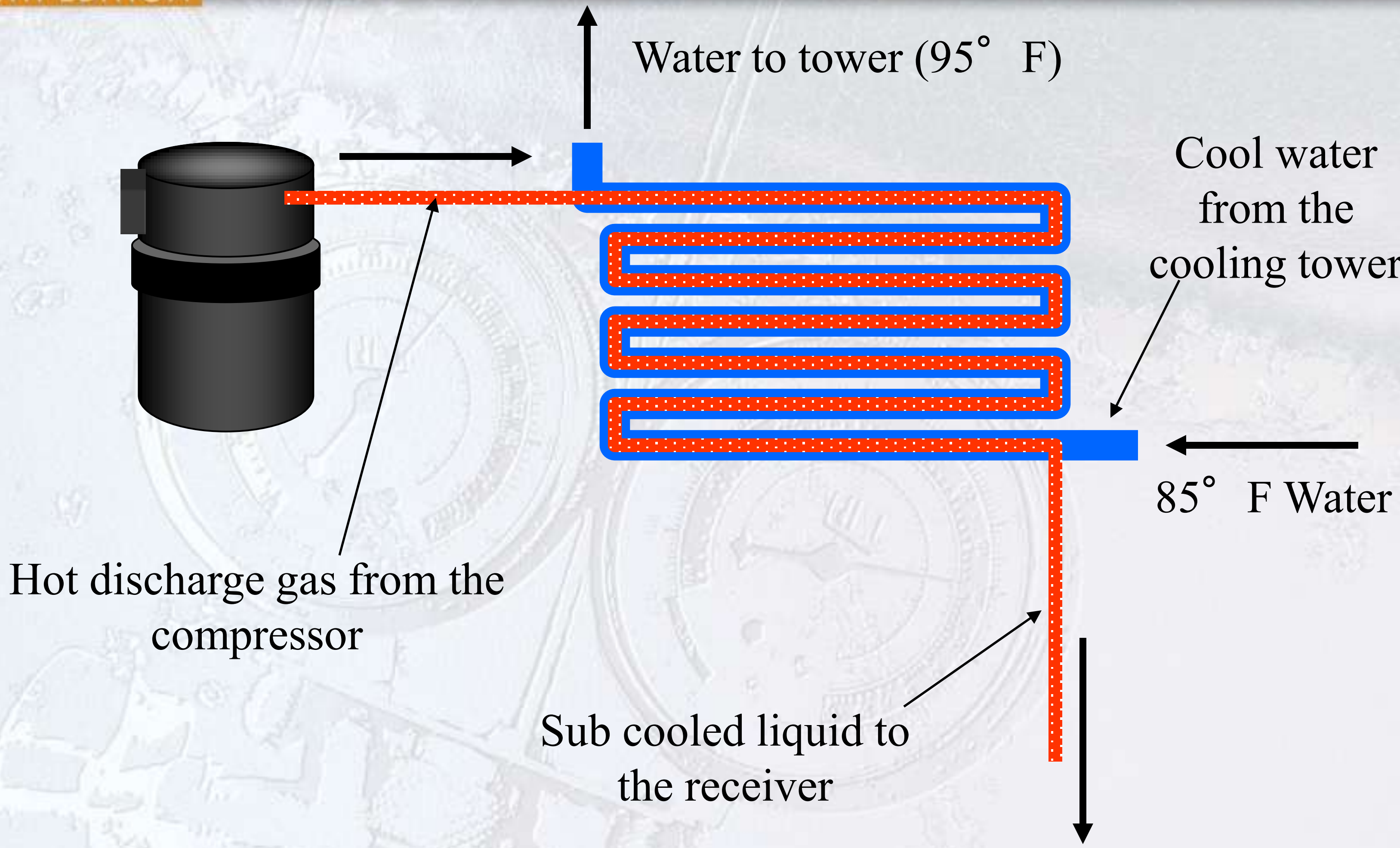
- Heat exchange surface that rejects system heat
- Rejects sensible heat
  - Desuperheating vapor refrigerant from the compressor
  - Subcools refrigerant at the outlet of the condenser
- Rejects latent heat during the condensing process
- The greatest amount of heat is transferred during the change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

WATER-COOLED CONDENSERS

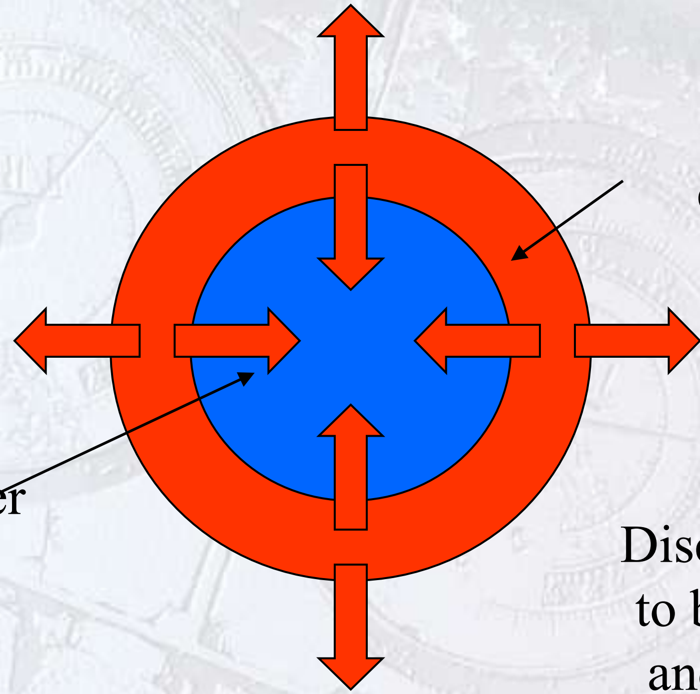
- More efficient than air-cooled condensers
- Water temperature can be maintained
- Water temperature directly affects system pressures
- Three types of water-cooled condensers
  - Tube within a tube condenser
  - Shell and coil condenser
  - Shell and tube condenser

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


Water to tower (95° F)
Cool water from the cooling tower
85° F Water
Hot discharge gas from the compressor
Sub cooled liquid to the receiver

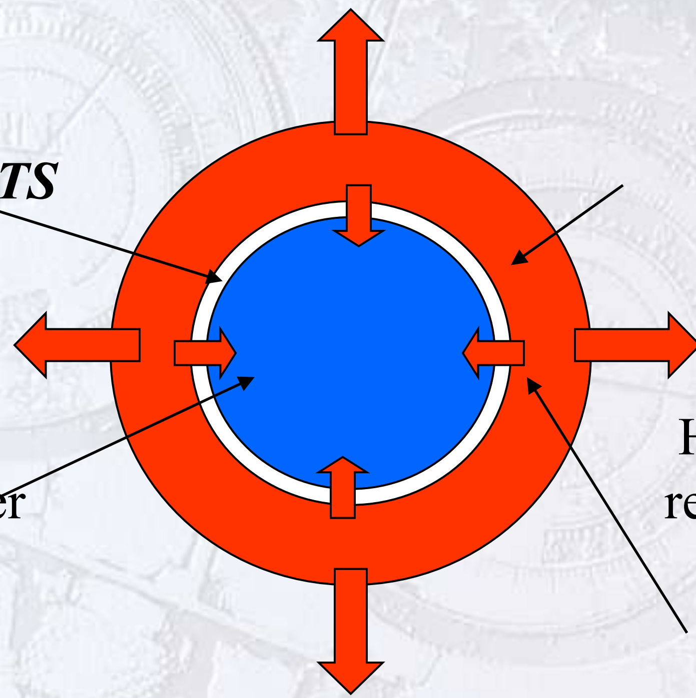
Cross-Section of a tube within a tube condenser

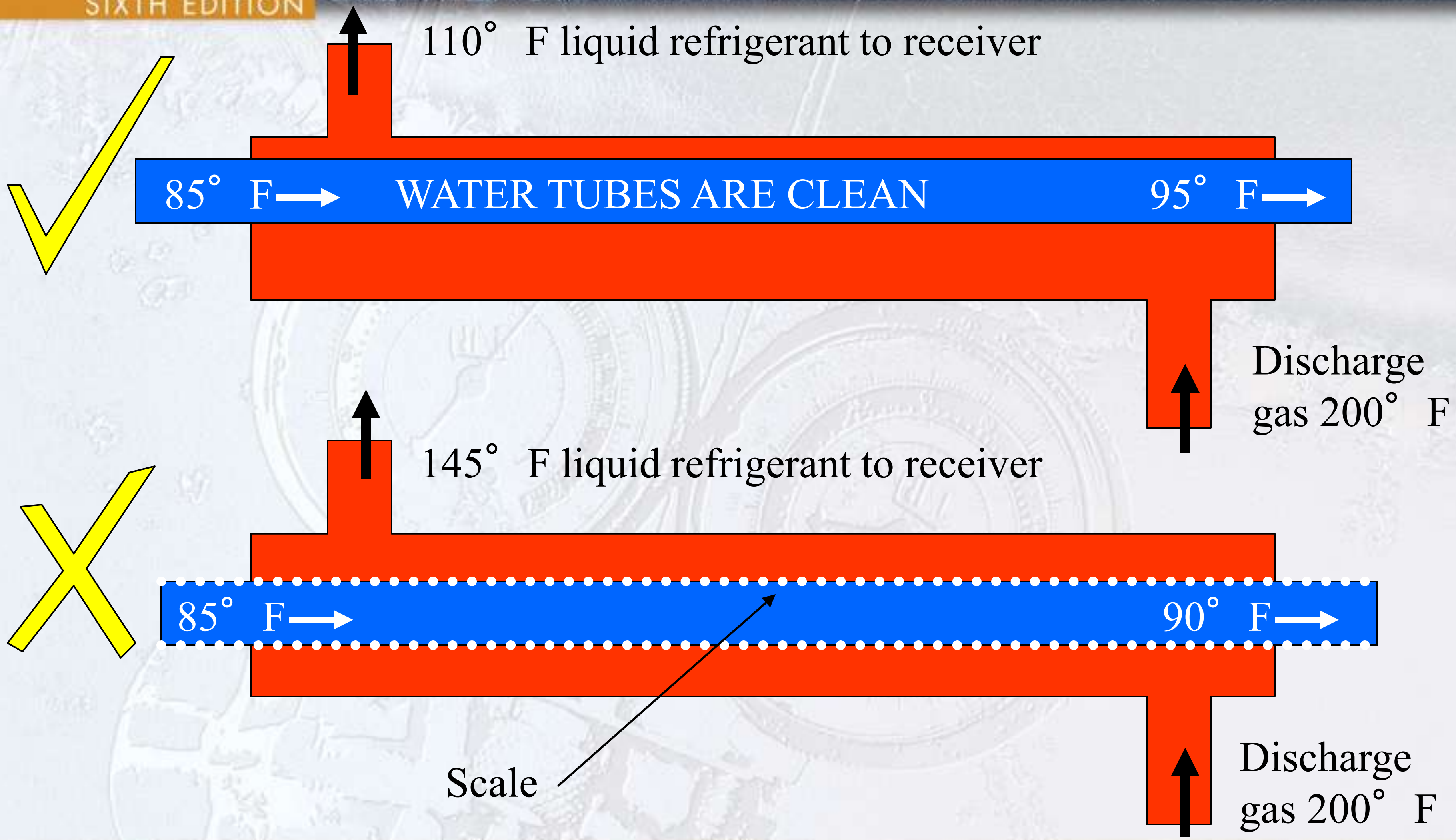


MINERAL DEPOSITS

- 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

Cross-Section of a tube within a tube condenser

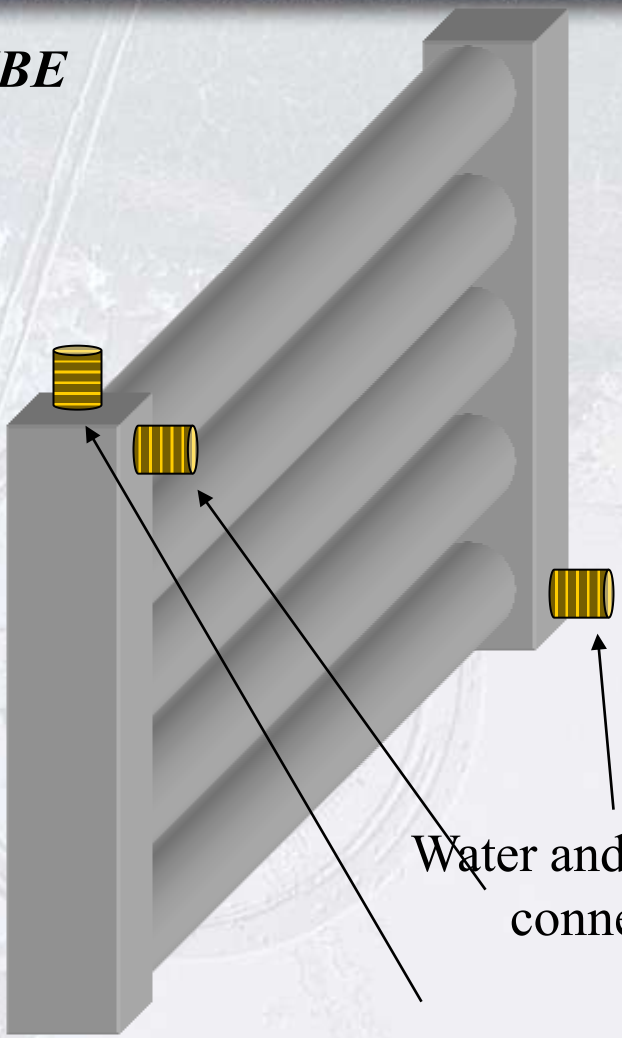



110° F liquid refrigerant to receiver
85° F
WATER TUBES ARE CLEAN
95° F
Discharge gas 200° F
145° F liquid refrigerant to receiver
85° F
90° F
Scale
Discharge gas 200° F

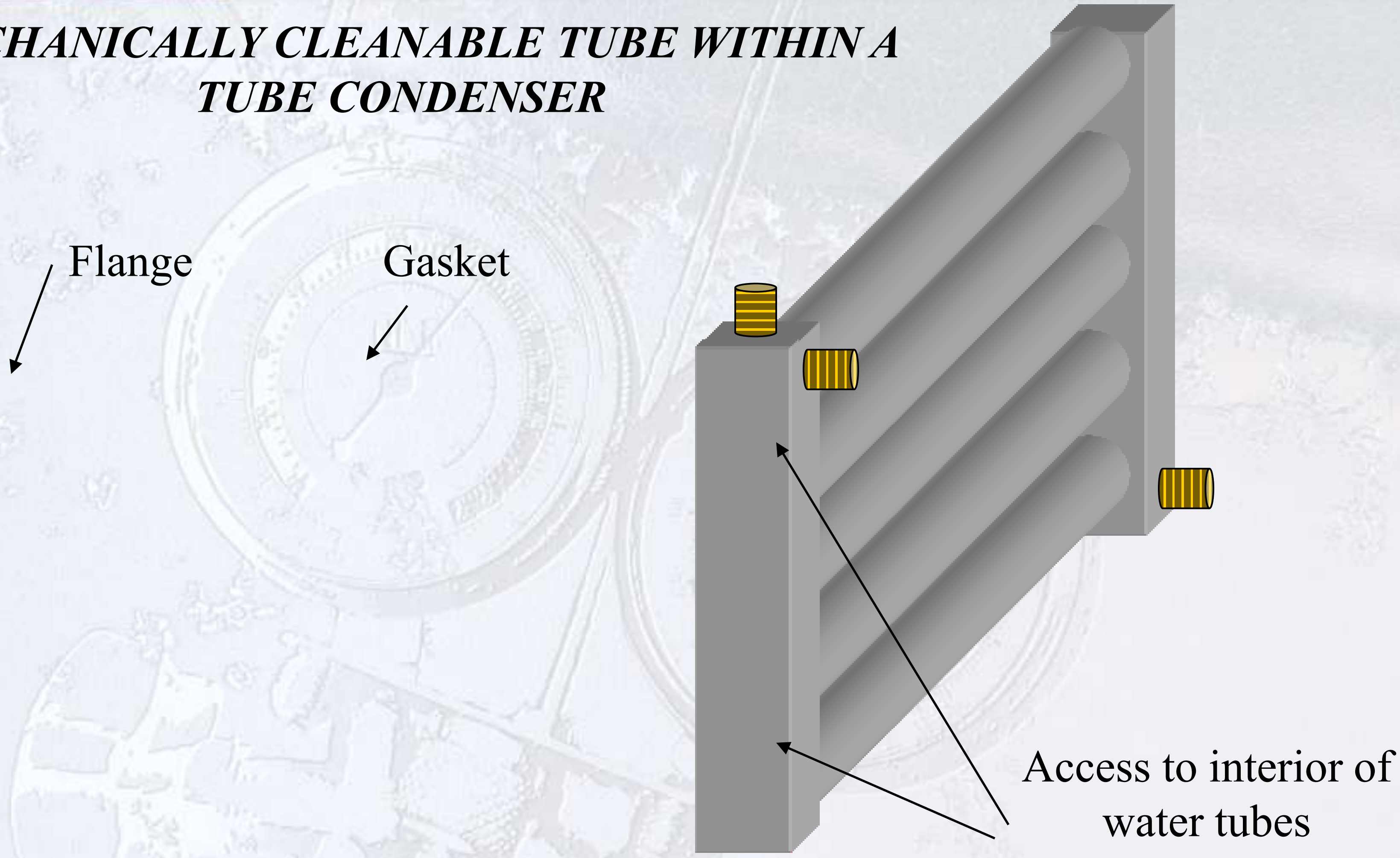
MECHANICALLY CLEANABLE CONDENSERS

- 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

MECHANICALLY CLEANABLE TUBE WITHIN A TUBE CONDENSER



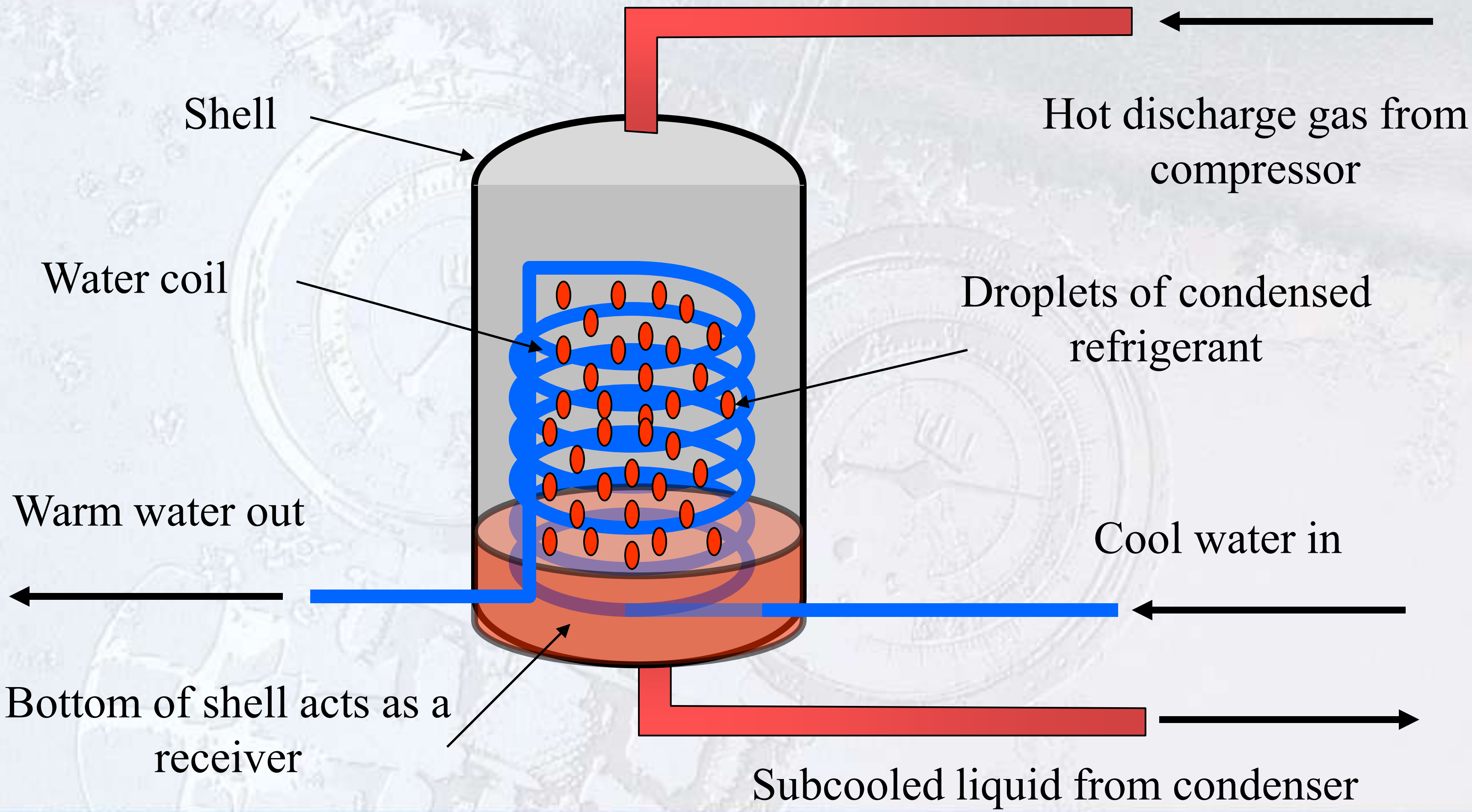
MECHANICALLY CLEANABLE TUBE WITHIN A TUBE CONDENSER



SHELL AND COIL CONDENSERS

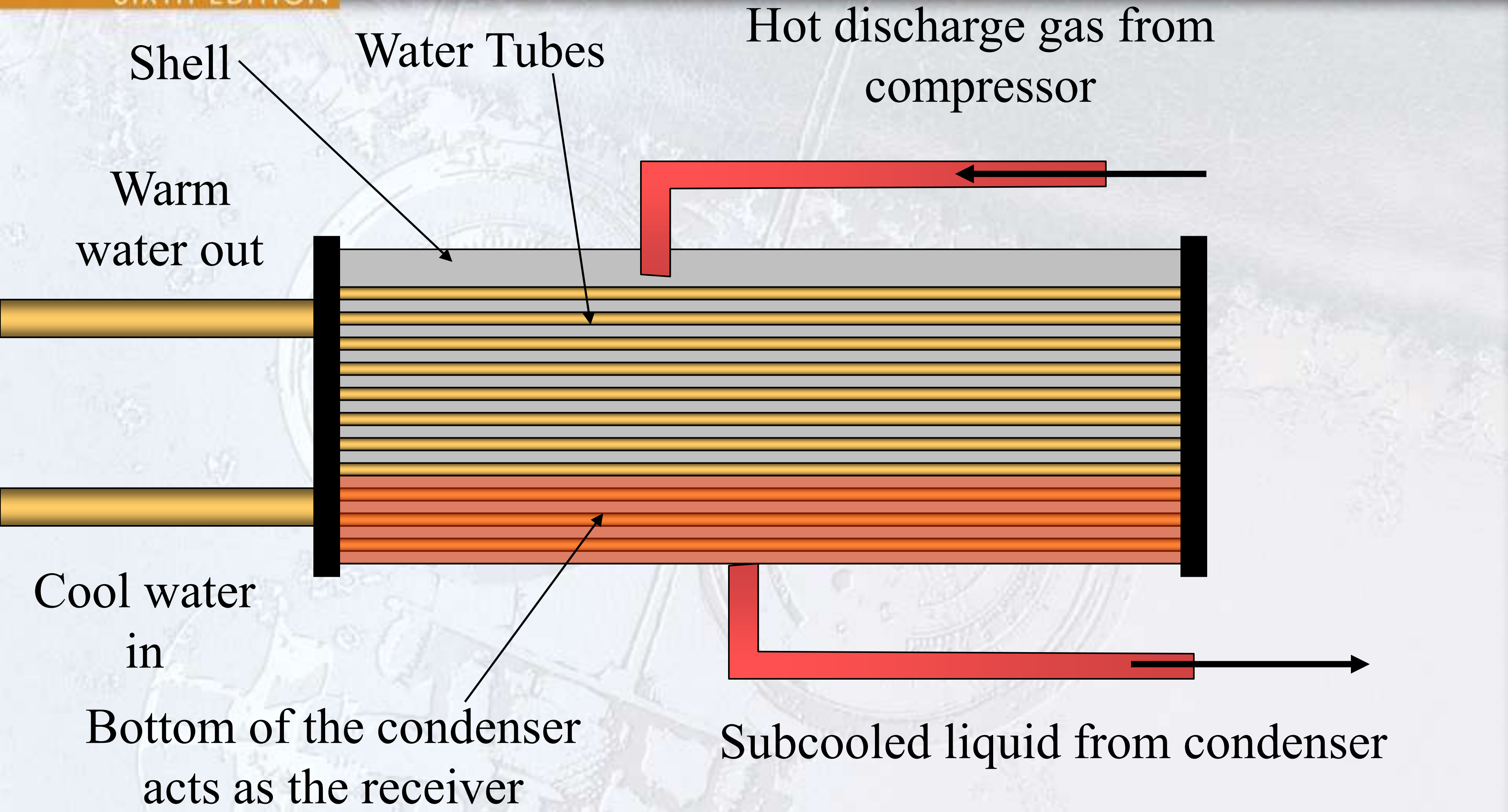
- Coil of tubing enclosed in a welded shell
- Water flows through the coil
- Refrigerant from the compressor is discharged into the shell
- The shell also acts as the receiver
- When refrigerant comes in contact with the cool coil, it condenses and falls to the bottom
- This condenser must be cleaned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

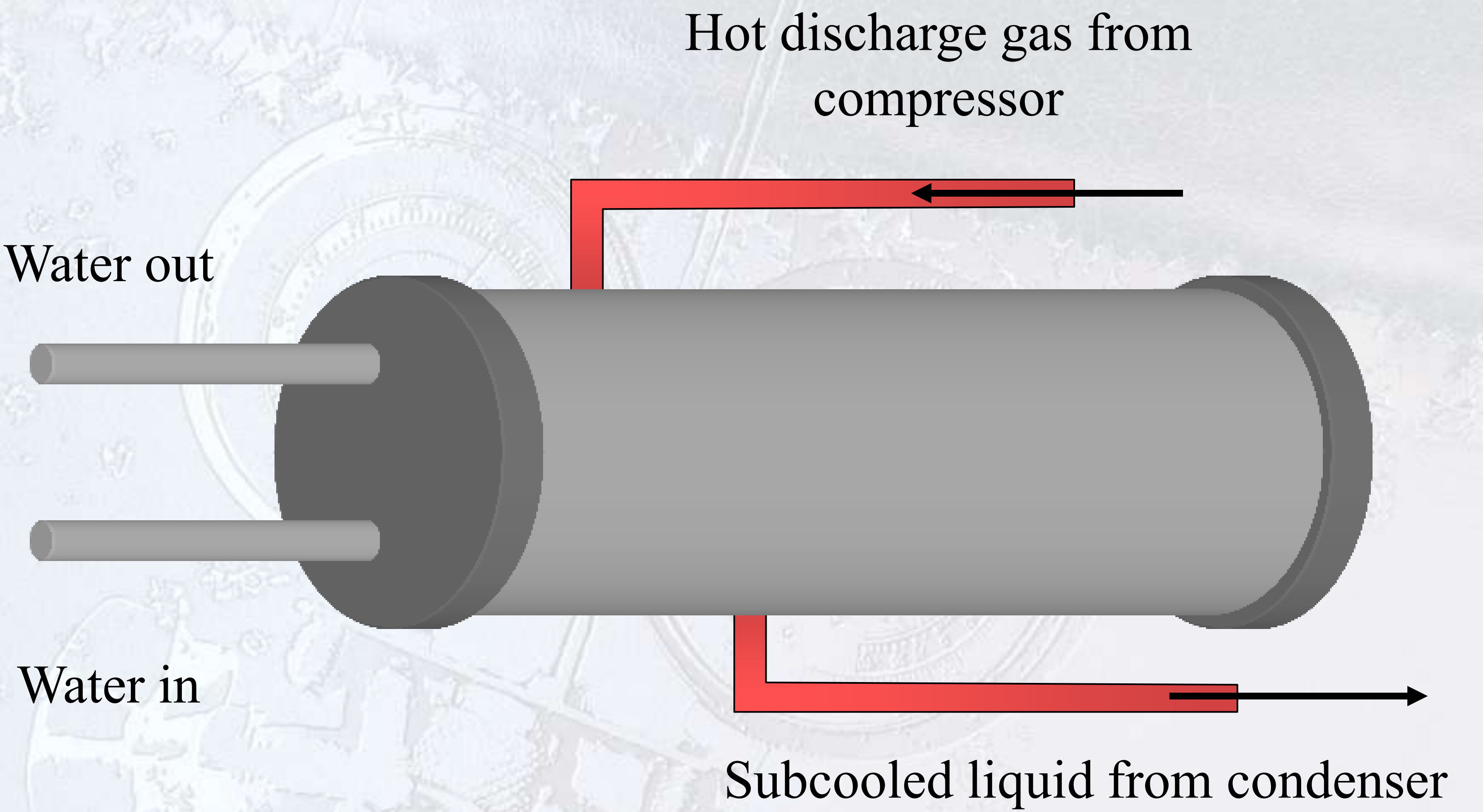
Shell and Coil Condenser

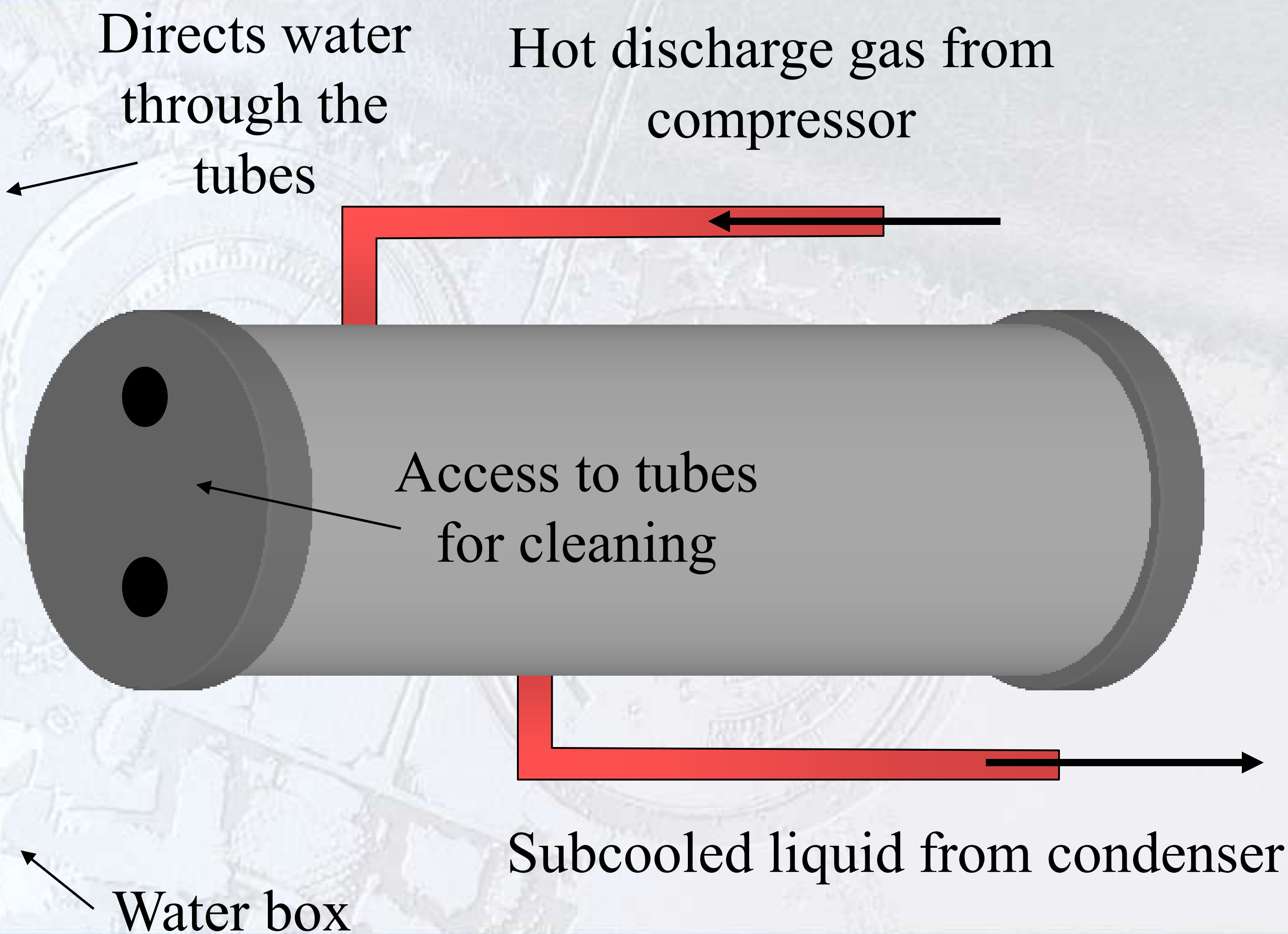


SHEL AND TUBE CONDENSERS

- 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


Shell
Water Tubes
Hot discharge gas from compressor
Warm water out
Cool water in
Bottom of the condenser acts as the receiver
Subcooled liquid from condenser

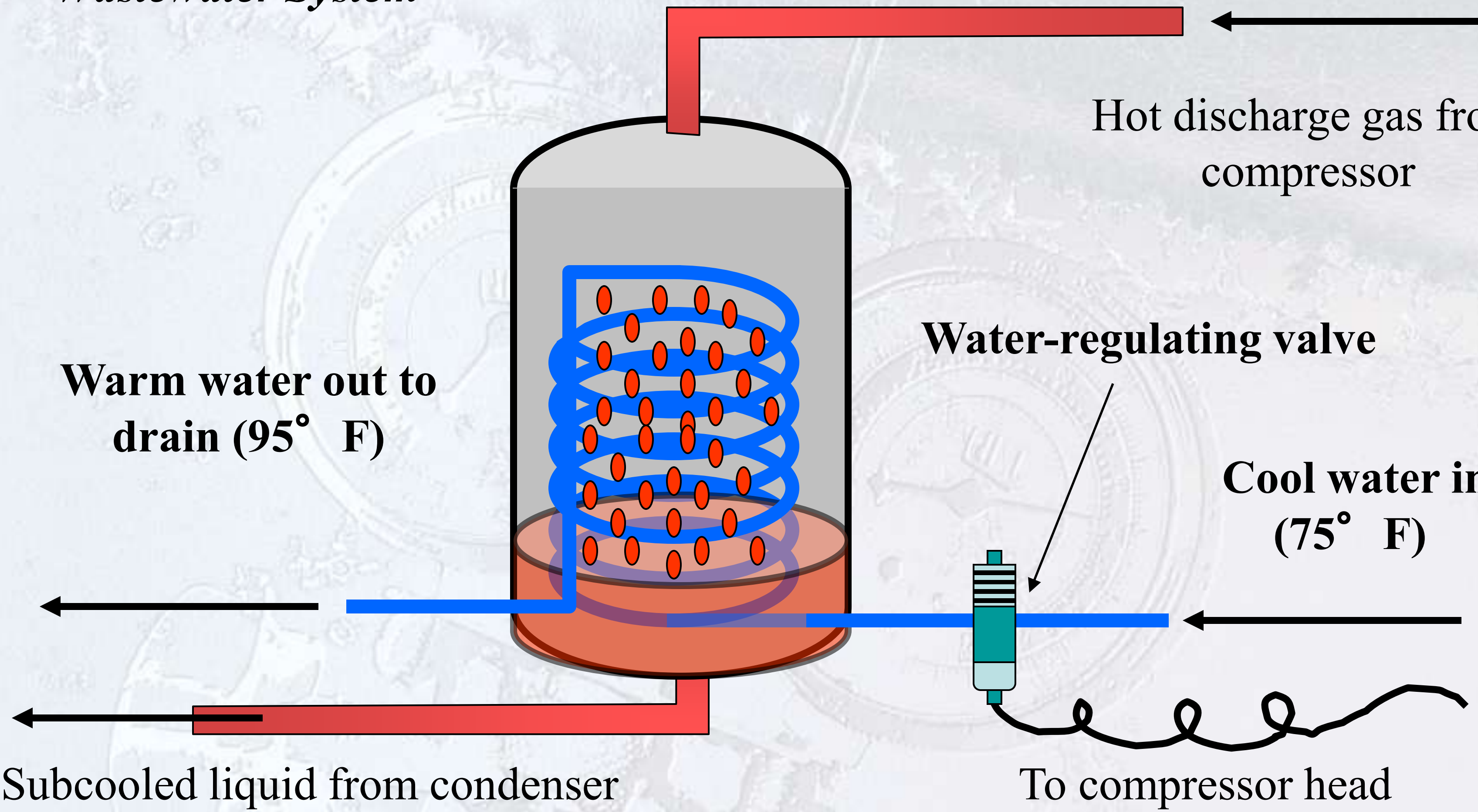

Hot discharge gas from compressor
Water out
Water in
Subcooled liquid from condenser


Directs water through the tubes
Hot discharge gas from compressor
Access to tubes for cleaning
Subcooled liquid from condenser
Water box

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

Wastewater System



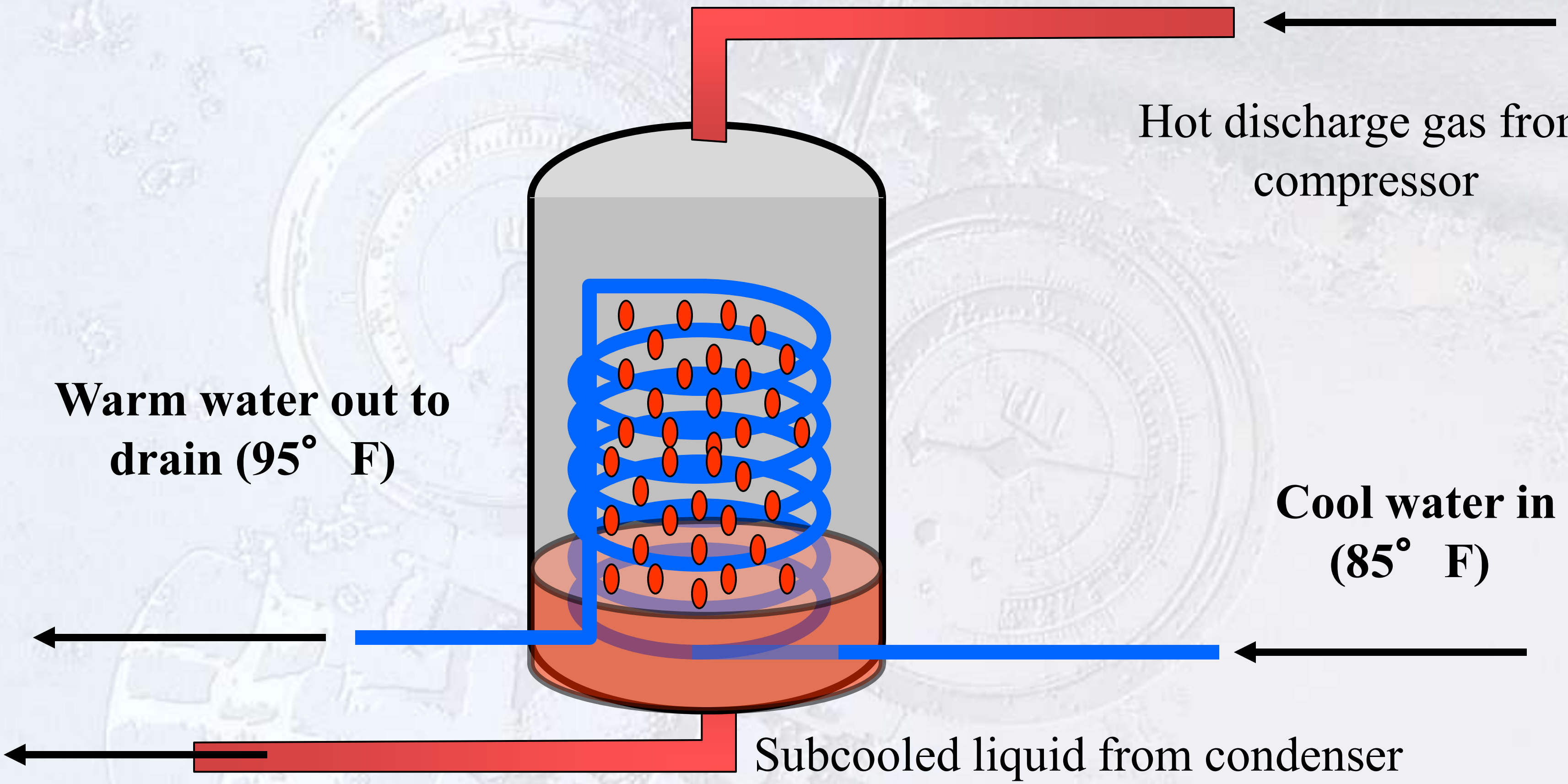
REFRIGERANT-TO-WATER TEMPERATURE RELATIONSHIP FOR WASTEWATER SYSTEMS

- 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

RECIRCULATED WATER SYSTEMS

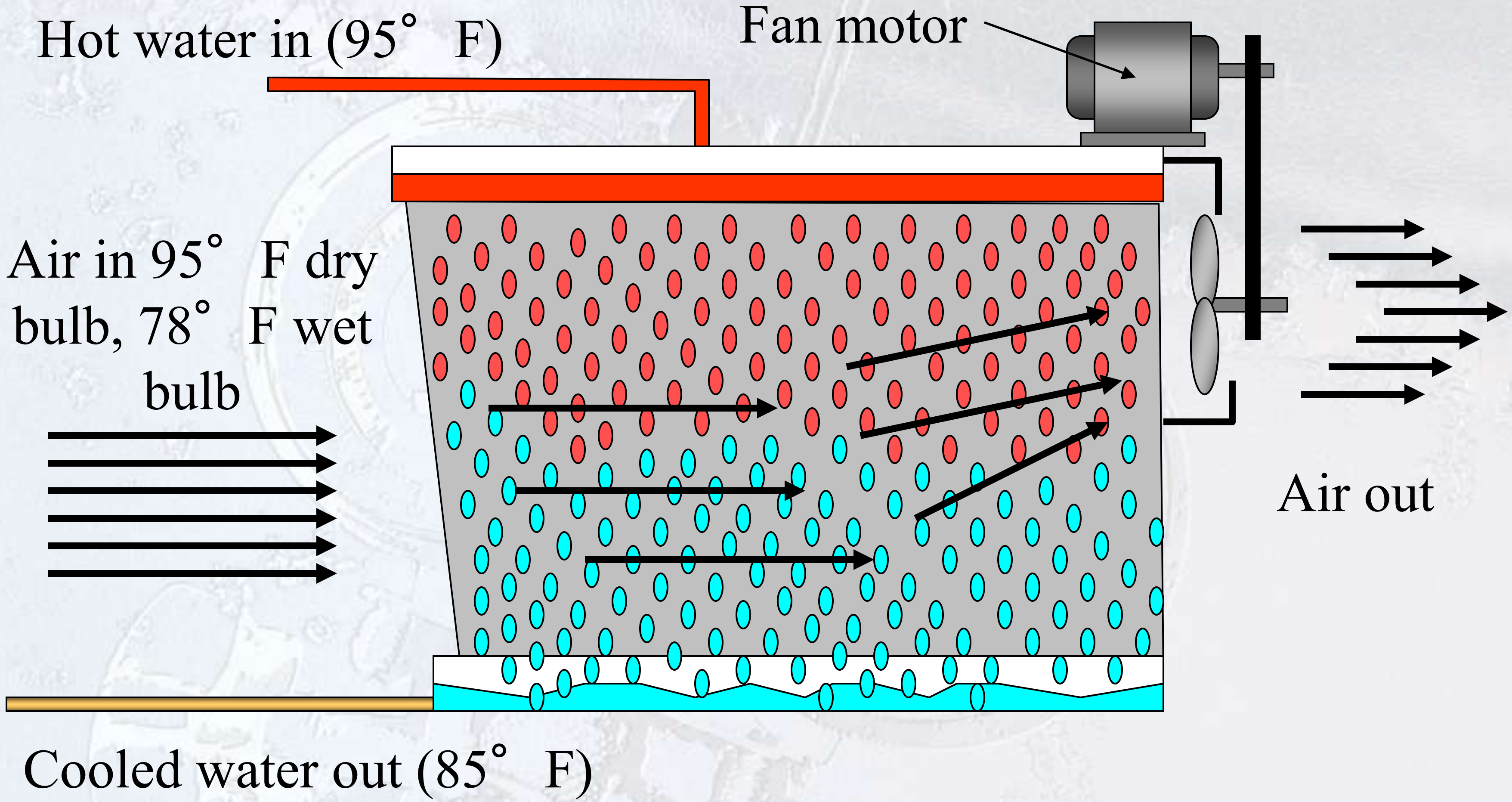
- The water flowing through the condenser is pumped to a remote location, cooled and reused
- Design water temperature is 85° F
- A water flow rate of 3.0 gpm per ton of refrigeration is required to absorb the heat rejected by the system condenser
- The water leaving the condenser is about 95° F
- There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

Recirculated Water System



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


Hot water in (95° F)
Fan motor
Air in 95° F dry bulb, 78° F wet bulb
Air out
Cooled water out (85° F)

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

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

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

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

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

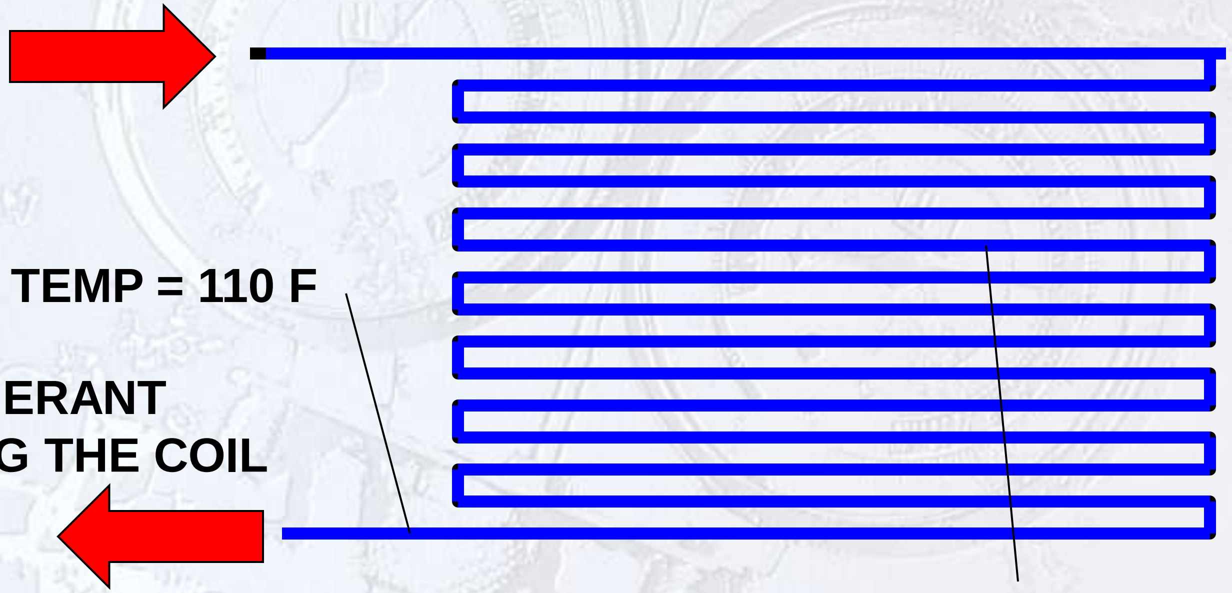
CALCULATING SUBCOOLING

Refrigerant R-134a

CONDENSER SUBCOOLING = 125 F – 110 F = 15 F

REFRIGERANT ENTERING THE COIL

184 psig (125° F)



OUTLET TEMP = 110 F

REFRIGERANT LEAVING THE COIL

CONDENSER SATURATION TEMPERATURE = 125 F

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

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

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

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

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

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

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

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

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

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