

Refrigeration & Air Conditioning Technology
SIXTH EDITION

SECTION 5

COMMERCIAL REFRIGERATION

UNIT 21

EVAPORATORS AND THE REFRIGERATION SYSTEM

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UNIT OBJECTIVES

After studying this unit, the reader should be able to

- Define high-, medium-, and low-temperature refrigeration.
- Determine the boiling temperature in an evaporator.
- Identify different types of evaporators.
- Describe a parallel-flow, plate-and-fin evaporator.
- Describe multiple- and single-circuit evaporators.
- Describe how a voltmeter is used to troubleshoot an electrical circuit.

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REFRIGERATION

- Process of moving heat from a place where it is not wanted to a place where it makes little or no difference
- Fresh food is maintained at about 35° F
- Heat travels naturally from a warmer substance to a cooler substance
- Mechanical refrigeration is required when heat is to be transferred from a cooler substance to a warmer substance

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REFRIGERATION (cont'd)

- Air conditioning is considered to be high temperature refrigeration
 - The evaporator coil is typically at about 40° F
 - The cooled air is mixed with the air in the room
- Commercial refrigeration systems
 - Some are self-contained, plug-in appliances
 - Can be individual boxes with remote condensing units
 - Several boxes can be served by one large compressor or by a rack of compressor piped in parallel with each other

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REFRIGERATION TEMPERATURE RANGES

- High temperature refrigeration
 - Box temperatures range from 47° F to 60° F
- Medium temperature refrigeration
 - Box temperatures range from 28° F to 40° F
- Low temperature refrigeration
 - Box temperatures range from -20° F to 0° F
 - Lower temperature are used for special applications

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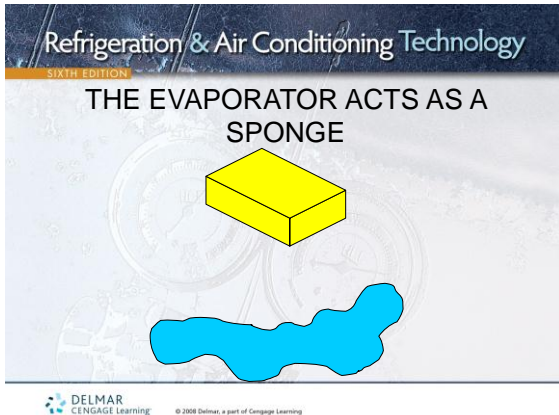
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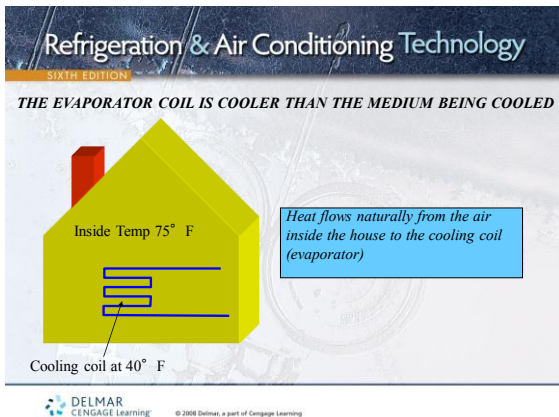
THE EVAPORATOR

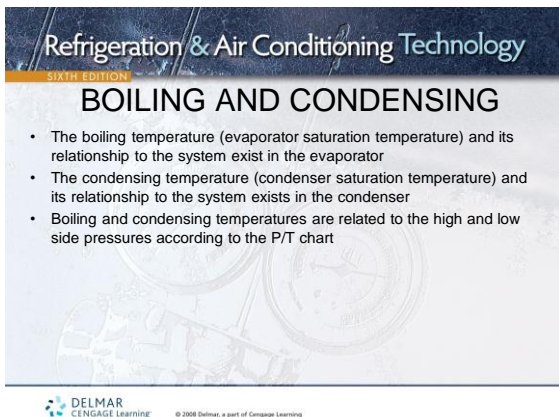
- Responsible for absorbing heat into the refrigeration system
- The evaporator is maintained at a temperature that is lower than the medium being cooled
- Removes both latent and sensible heat from the air in the refrigerated box
 - Latent heat is in the form of moisture
 - Sensible heat reduces air and product temperature

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PORTION OF A PRESSURE/TEMPERATURE CHART

° F	R-12	R-22	R-134a	R-410a
39	36.1	67.1	34.1	
40	37.0	68.5	35.1	118.3
41	37.9	70.0	36.0	120.5
42	38.8	71.4	37.0	

THE TEMPERATURES ARE LOCATED IN THE LEFT COLUMN
THE PRESSURES ARE LOCATED IN THE RIGHT COLUMNS


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WHAT IS THE PRESSURE OF R-22 AT 41 DEGREES?

° F	R-12	R-22	R-134a	R-410a
39	36.1	67.1	34.1	
40	37.0	68.5	35.1	118.3
41	37.9	70.0	36.0	120.5
42	38.8	71.4	37.0	

THE POINT AT WHICH THE ROW AND COLUMN CROSS WILL GIVE US
THE PRESSURE OF R-22 AT 41° F



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THE EVAPORATOR AND THE BOILING TEMPERATURE

- Boiling temperature determines the evaporator coil temperature
- Technicians must know the correct temperatures and pressures for various systems under different operating conditions
- Relationships exist between air temperatures and evaporator coil temperatures


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REMOVING MOISTURE

- Dehumidifying is the process of removing moisture
- Moisture removal is similar in similar systems
- Evaporator coil load changes as the return air temperature changes
- Removal of moisture is a latent heat transfer
- Latent heat is also referred to as *hidden heat*
- The evaporator facilitates heat transfer between the conditioned space and the refrigerant in the system

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HEAT EXCHANGE CHARACTERISTICS OF THE EVAPORATOR

- Common materials used are copper, aluminum, steel, brass and stainless steel
- Corrosion factor and application determines the materials used for a particular evaporator
- Rapid heat transfer rate between two liquids
- Slower heat transfer rate between two vapors

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HEAT EXCHANGE CHARACTERISTICS OF THE EVAPORATOR (cont'd)

- Film factor
 - Relationship between the medium giving up heat and the heat exchange surface
 - Related to the velocity of medium passing over the coil
 - If velocity is low, the film acts as an insulator
- Temperature difference between two mediums
 - Large temperature difference = high heat transfer rate
 - Small temperature difference = low heat transfer rate

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EVAPORATOR TYPES

- Natural convection (draft) evaporators
 - Made up of bare tubes or pipes
 - Physically large, very low air velocity
 - Located high, near the ceiling of a walk-in cooler
- Mechanical draft evaporators
 - Use blowers or fans to move air across the coil
 - Improved heat transfer rate
 - Physically smaller than natural draft evaporators

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CEILING OF WALK-IN BOX

The diagram shows a cross-section of a walk-in box. At the top, a horizontal brown bar represents the ceiling. Below it, six orange circles represent the cross-sections of evaporator tubes. Red arrows show air rising from the bottom of the box, passing over the tubes, and then moving back down the sides. Blue arrows point downwards from the tubes, indicating the flow of air. The text 'CROSS SECTION OF EVAPORATOR TUBES' points to the orange circles, and 'WARMER AIR FROM BOX RISES' points to the upward flow of air.

WARMER AIR FROM BOX RISES

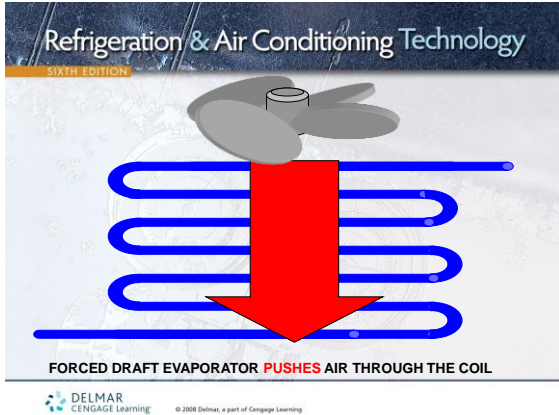
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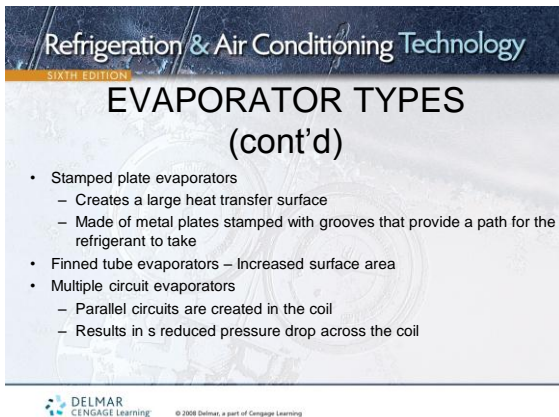
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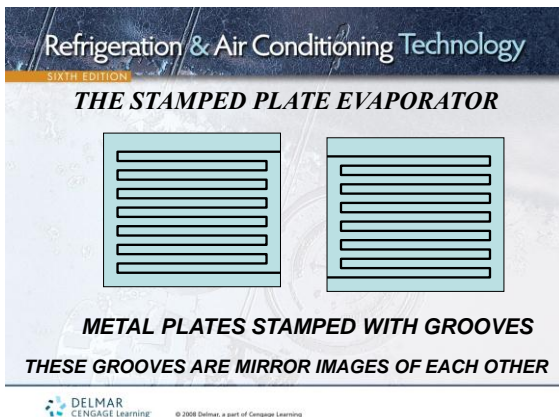
The diagram shows a red arrow pointing upwards through a blue coil. The coil is represented by a series of horizontal blue lines that curve upwards at the ends. A small grey cylinder is at the top of the red arrow. The text 'INDUCED DRAFT EVAPORATOR PULLS AIR THROUGH THE COIL' is at the bottom.

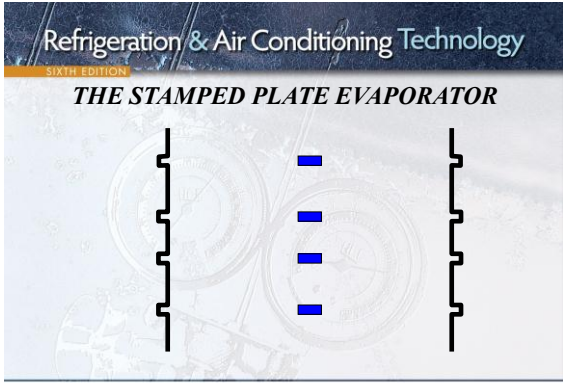
INDUCED DRAFT EVAPORATOR PULLS AIR THROUGH THE COIL

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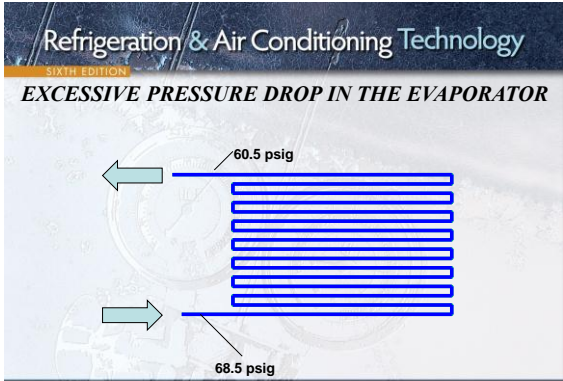






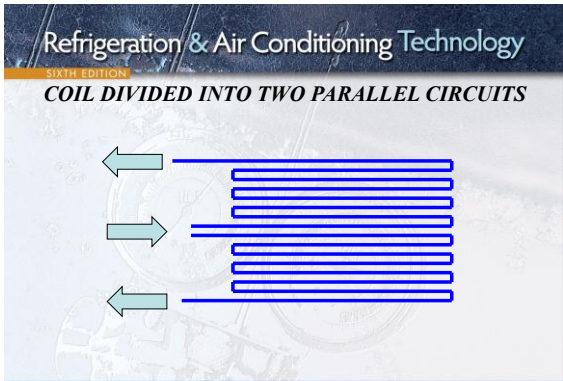
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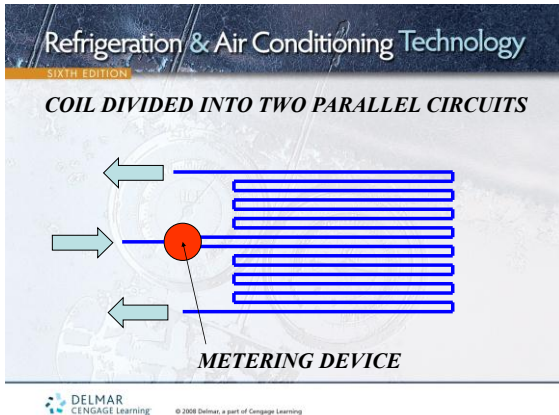
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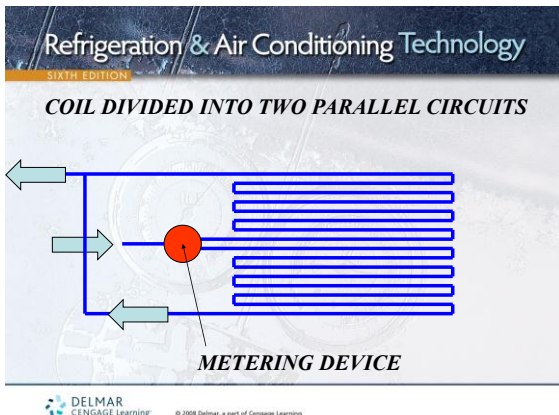
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EVAPORATOR EVALUATION – MEDIUM TEMPERATURE WALK-IN BOX

- R-134a box at 35° F, forced draft, single circuit
 - 65% liquid, 35% vapor enters the coil
 - Coil is about 20 degrees colder than the box
 - Pressure is 18.4 psig (20° F from P/T chart)
 - As refrigerant boils, more of the liquid vaporizes
 - More liquid present in the coil increases its efficiency
 - No liquid refrigerant should leave the evaporator

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LATENT HEAT IN THE EVAPORATOR

- Latent heat is more concentrated than sensible heat
- Latent heat transfers result in changes of state
- The greatest heat transfers take place during latent heat transfers
- 1.0 btu is required to change the temperature of one pound of water one degree Fahrenheit
- 970.3 btu are required to change one pound of water at 212° F to one pound of steam at 212° F

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THE FLOODED EVAPORATOR

- 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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THE DRY-TYPE EVAPORATOR

- Evaporators are considered to be "dry" when all of the liquid boils before leaving the coil
- Evaporator superheat must be calculated
- Superheat = Evaporator outlet temperature minus the Evaporator saturation temperature
- Normal evaporator superheat is between 8 and 12° F
- High superheat indicates an underfed evaporator

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EVAPORATOR SUPERHEAT

- Defined as the evaporator outlet temperature minus the evaporator saturation temperature
- The sensible heat that is added to the refrigerant at the outlet of the evaporator after all of the liquid has boiled off into a vapor
- Low superheat = Overfed evaporator
- High superheat = Underfed (starved) evaporator

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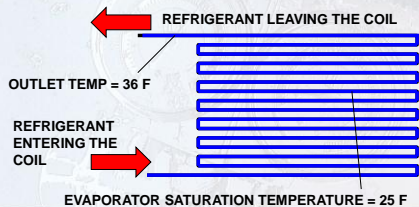
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CALCULATING SUPERHEAT

Refrigerant R-XYZ

$$\text{EVAPORATOR SUPERHEAT} = 36^\circ\text{F} - 25^\circ\text{F} = 11^\circ\text{F}$$


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HOT PULL DOWNS

- Excessively loaded evaporators
- Occurs when the box has warmed up considerably
- System is not operating under design conditions
- Evaporator superheat *may* be high
- Evaporator superheat correct near design conditions
- System should stabilize before measuring superheat
- An overfed, dry-type evaporator with no superheat is said to be *flooded*

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PRESSURE DROP IN THE EVAPORATOR

- The pressure drop through the coil should be as low as possible
- When the pressure drop is high, a multiple circuit evaporator is used
- Each circuit should be fed with the same amount of refrigerant (also liquid/vapor percentages)
- Reasons for uneven feeding include blocked distributors, dirty coil, uneven air distribution and different length coil circuits

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LIQUID-COOLING EVAPORATORS

- Commonly called chillers or chiller barrels
- Different type of evaporator is used
- Dry-type, multi-circuit coils
- Usually operate with 8° F to 12° F of superheat
- Liquid-side problems include
 - Mineral deposits
 - Poor liquid circulation

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EVAPORATORS FOR LOW-TEMPERATURE APPLICATIONS

- Evaporators are designed differently
- Fins are spaced far apart to accommodate frost buildup without sacrificing system operation or airflow through the coil
- Have some means to periodically remove frost
 - Hot gas defrost sends compressor discharge gas to the evaporator coil to melt the ice
 - Electric heaters can also be used

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HOT GAS DEFROST

- Compressor discharge gas pumped directly to the evaporator coil during the defrost cycle
- Defrost is controlled by a solenoid valve
- Hot gas from the compressor condenses to a liquid in the evaporator coil
- Liquid from the evaporator vaporizes in the accumulator before returning to the compressor
- During defrost, the compressor operates with an increased load, increasing the amperage draw

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ELECTRIC DEFROST

- Electric heating elements are located next to the evaporator coil
- The compressor and evaporator fan motor are not operating during defrost
- Fan motor operation would circulate hot air throughout the box during defrost
- At the end of the defrost cycle, the compressor cycles on before the fan to allow the evaporator coil to get cold before the fan is energized

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UNIT SUMMARY - 1

- Refrigeration is the process of transferring heat from a place where it is not wanted to a place where it makes little or no difference
- Heat flows naturally from warmer substances to cooler substances
- Common refrigeration temperature ranges are high, medium and low
- The evaporator is responsible for absorbing heat into the refrigeration system

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UNIT SUMMARY - 2

- The evaporator is maintained at a temperature that is lower than the medium being cooled
- The evaporator absorbs sensible and latent heat
- Sensible heat lowers the temperature in the box
- Latent heat lowers the humidity in the box
- Boiling temperatures and pressures are related by the pressure/temperature relationship
- Boiling temperature determines the coil temperature



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UNIT SUMMARY - 3

- Evaporators are commonly constructed of copper, steel, aluminum, stainless steel and brass
- Large temperature differences between the coil and the box result in a higher heat transfer rate
- Common evaporator types include the natural draft, forced draft and stamped plate
- Fins are used to increase the heat transfer surface
- Evaporators can be dry-type or flooded



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UNIT SUMMARY - 4

- Evaporator superheat is the evaporator outlet temp. minus the evaporator saturation temp.
- High superheat = Underfed evaporator
- Low superheat = Overfed evaporator
- Multi-circuit evaporators reduce the pressure drop through the coil
- Evaporators used for liquid cooling are chillers
- Low temperature evaporators are defrosted by hot gas or electric strip heaters



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