

Refrigeration & Air Conditioning Technology  
SIXTH EDITION

## Section 1: Theory of Heat

### Unit 3: Refrigeration and Refrigerants

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## Unit Objectives

After studying this chapter, you should be able to:

- Discuss applications for high-, medium-, and low temperature refrigeration.
- Describe the term ton of refrigeration.
- Describe the basic refrigeration cycle.
- Explain the relationship between pressure and the boiling point of water or other liquids.
- Describe the function of the evaporator or cooling coil.
- Explain the purpose of the compressor.
- List the compressors normally used in residential and light commercial buildings.
- Discuss the function of the condensing coil.

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## Unit Objectives

After studying this chapter, you should be able to:

- State the purpose of the metering device.
- List four characteristics to consider when choosing a refrigerant for a system.
- List the designated colors for refrigerant cylinders for various types of refrigerants.
- Describe how refrigerants can be stored or processed while refrigeration systems are being serviced.
- Plot a refrigeration cycle for refrigerants (r-22, r-12, r-134a, and r-502) on a pressure/enthalpy diagram.

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## Unit Objectives

After studying this chapter, you should be able to:

- Plot a refrigeration cycle on a pressure/enthalpy diagram for refrigerant blends r-404a and r-410a.
- Plot a refrigeration cycle on a pressure/enthalpy diagram for a refrigerant blend (r-407c) that has a noticeable temperature glide.

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## INTRODUCTION TO REFRIGERATION

- Cooling to preserve products and provide comfort
- 1900s were the beginnings of mechanical refrigeration systems
- Refrigeration process temperature ranges
  - High temperature – Air conditioning (comfort)
  - Medium temperature – Fresh food preservation
  - Low temperature – Frozen food preservation

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## REFRIGERATION

- Process of transferring heat from a place where it is objectionable to a place where it makes little or no difference
- Heat naturally flows from a warmer substance to a cooler substance
- Heat will flow naturally from a 100° F house if the outside temperature is 80° F
- Mechanical refrigeration is needed if the house is 80° F and the outside temperature is 100° F

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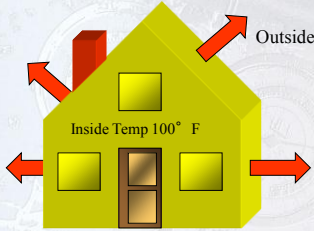
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*Heat flows naturally from a warmer substance to a cooler substance*



Inside Temp 100° F

Outside temperature 80° F

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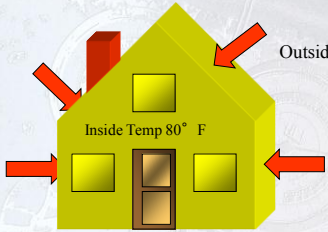
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*Heat flows naturally from a warmer substance to a cooler substance*



Inside Temp 80° F

Outside temperature 100° F

*Mechanical refrigeration would be needed to cool this house*

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**RATING REFRIGERATION EQUIPMENT**

- It takes 144 btu to melt one pound of ice at 32° F
- 2,000 pounds of ice (1 ton) will require 288,000 btu to melt (144 btu x 2,000 pounds)
- If the melting of 1 ton of ice takes place in one day (24 hours), 12,000 btu must be absorbed by the ice every hour (288,000 btu / 24 hours)
- 12,000 btu/hr = 200 btu/min = 1 ton of refrigeration

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### THE REFRIGERATION PROCESS

- Heat is pumped from a cool box to a warm room
- Pumping of heat is similar to pumping water uphill
- Air conditioners pump heat from inside to the outside
  - Inside temperature 75° F, Outside temperature 95° F
  - Cooling (indoor) coil temperature 40° F
  - Condenser (outdoor) coil temperature 125° F
  - Indoor heat travels to the indoor coil
  - System heat flows from the outdoor coil to the outside air


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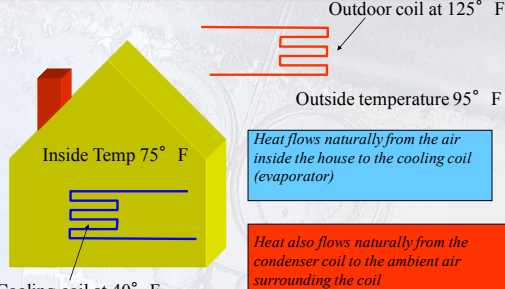
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Outdoor coil at 125° F


Outside temperature 95° F

Inside Temp 75° F

Cooling coil at 40° F

*Heat flows naturally from the air inside the house to the cooling coil (evaporator)*

*Heat also flows naturally from the condenser coil to the ambient air surrounding the coil*


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### TEMPERATURE AND PRESSURE RELATIONSHIP

- Water boils at 212° F at atmospheric pressure (29.92 in. Hg)
- Water boils at 250° F if pressure is increased to 15 psig
- Water boils at 40° F if pressure is reduced to 0.248 in. Hg
- Refrigerants are substances that boil at low pressures and temperatures and condense at high pressures/temperatures
- Saturation temperature – Point at which the addition or removal of heat will result in a change of state
- During a change of state, the temperature remains constant


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## REFRIGERATION COMPONENTS

- Evaporator - Absorbs heat from area to be cooled
- Compressor – Creates pressure difference needed to facilitate refrigerant flow through the system
- Condenser - Rejects system heat
- Metering device – Regulates refrigerant flow to the evaporator

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## THE EVAPORATOR

- Heat exchange surface used to absorb heat
- Located on the low-pressure side of the system between the metering device and the compressor
- Operates at temperatures lower than the medium being cooled or conditioned
- Absorbs heat by boiling a low temperature liquid into a low temperature vapor

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## THE EVAPORATOR (cont'd)

- Refrigerant typically enters the evaporator as a liquid/vapor mix (75% liquid, 25% vapor)
- Superheat
  - The heating of a vapor above its saturation temperature
  - Ensures that no liquid refrigerant enters the compressor
  - Equal to the evaporator outlet temperature minus the evaporator saturation temperature
  - Design superheat is typically between 8° F and 12° F
- Superheated vapor does not follow a pressure/temperature relationship

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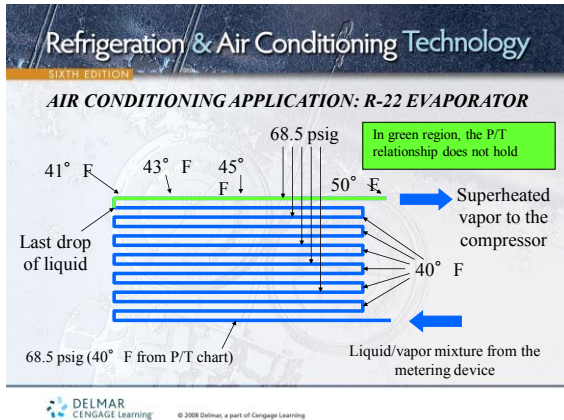
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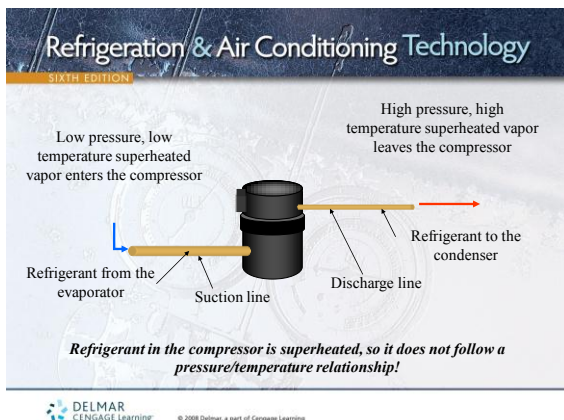
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### THE CONDENSER

- Rejects sensible and latent heat from the system that was absorbed by compressor and evaporator
- Located on the high-pressure side of the system
- The refrigerant condenses from a high temperature vapor to a high temperature liquid
- Condensing temperature is determined by the high side pressure in the system
- Refrigerant is subcooled at the outlet of the condenser

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### THE CONDENSER (cont'd)

- Subcooling
  - The cooling of liquid refrigerant below its saturation temperature
  - Standard air-cooled systems are designed to operate with a minimum of 10° F of subcooling
  - High efficiency condensers operate with more subcooling than standard efficiency systems
  - Determined by subtracting the condenser saturation temperature from the condenser outlet temperature

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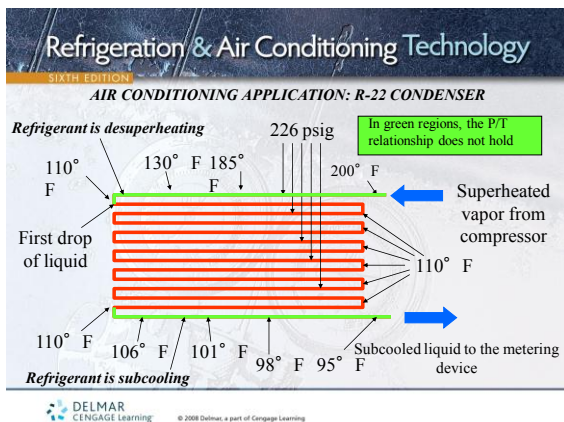
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### THE METERING DEVICE

- Controls the flow of subcooled liquid from the condenser to the evaporator
- Creates a pressure drop between the high and low pressure sides of the system
- About 25% of the liquid leaving the metering device immediately vaporizes (flash gas)
- Three commonly used metering devices are the capillary tube, automatic expansion valve and the thermostatic expansion valve

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### PUTTING IT TOGETHER: A WINDOW UNIT EXAMPLE

Indoors: 75° F

Outdoors: 95° F

Compressor

Condenser

Evaporator

Metering device

R-22

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### PUTTING IT TOGETHER: A WINDOW UNIT EXAMPLE

100% vapor

Saturated refrigerant

69 psig

50° F

200° F 278 psig

125° F

110° F

Outdoors: 95° F

278 psig

75% liquid  
25% vapor

69 psig (40° F)

R-22

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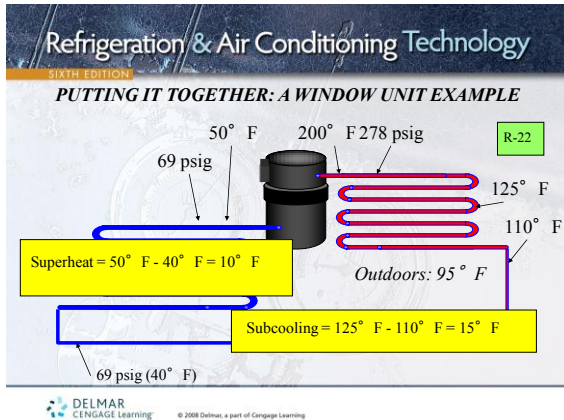
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REFRIGERANTS

- R-12 used primarily for high and medium temperature refrigeration applications (manufacture banned in 1996)
- R-22 used primarily in air conditioning applications ( slated for total phase-out in 2030)
- R-500 and R-502 banned in 1996
- R-134a – replacement for R-12 with retrofit
- Replacements for R-22 include R-410a and R-407c

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REFRIGERANTS MUST BE  
SAFE

- Designed to protect people from sickness, injury and death
- Proper ventilation is required
- Refrigerants can displace oxygen if permitted to accumulate
- Modern refrigerants are non-toxic
- When burned, toxic/corrosive gases are created

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## REFRIGERANTS MUST BE DETECTABLE

Methods used for detecting refrigerant leaks include:

- Soap bubble solution – pinpoints leaks
- Halide leak detector – uses an open flame
- Electronic leak detectors – general area leaks
- Ultraviolet leak detectors – pinpoints leaks
- Ultrasonic leak detectors – uses sound waves

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## GENERAL REFRIGERANT NOTES

- Refrigerants should boil at low temperatures at atmospheric pressure so that low temperatures can be obtained without going into a vacuum
- It is illegal to intentionally vent refrigerant to the atmosphere (Stiff fines for violations)
- Mandatory certification for technicians
- The EPA set refrigerant phase-out schedules
- Refrigerant cylinders and drums are color-coded

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## RECOVERY, RECYCLING AND RECLAIMING OF REFRIGERANTS

- Refrigerant recovery is mandatory during service and installation operations
- Intended to reduce the emissions of CFC, HCFC and HFC refrigerants
- Recovery equipment must be used according to manufacturer's instructions

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### PLOTTING THE REFRIGERATION CYCLE

- Pressure-enthalpy chart
  - Used to create a graphical representation of a system
  - Pressure scales on the vertical axis (psia)
  - Enthalpy scale along the bottom of the chart
  - Horseshoe curve represents the saturation curve
  - Refrigerant is saturated on and under the curve
- Enthalpy is defined as heat content

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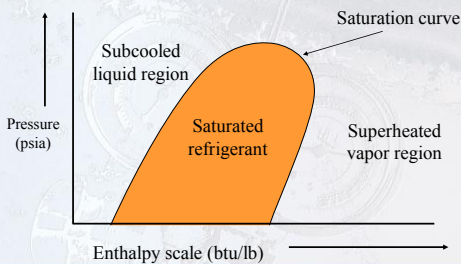
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### THE PRESSURE ENTHALPY CHART



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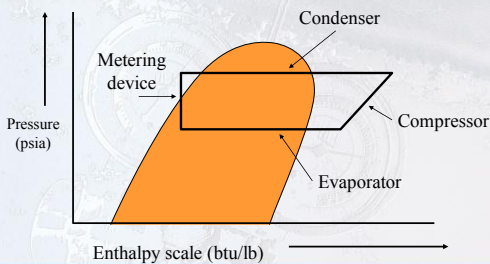
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### THE PRESSURE ENTHALPY CHART: A SAMPLE PLOT



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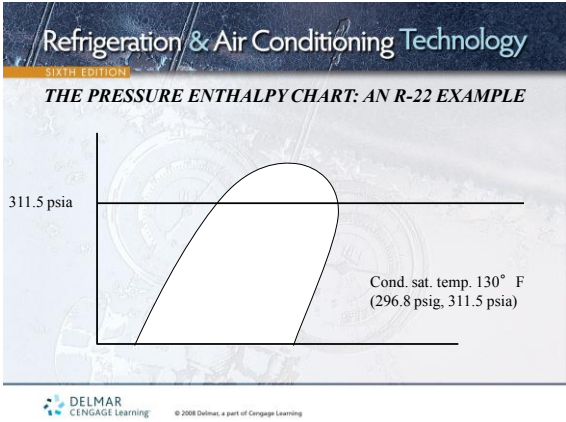
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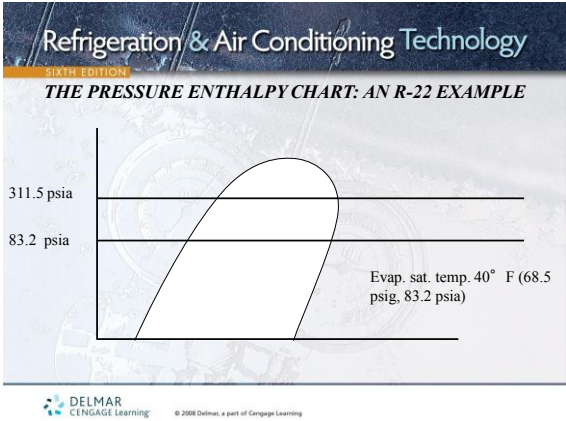
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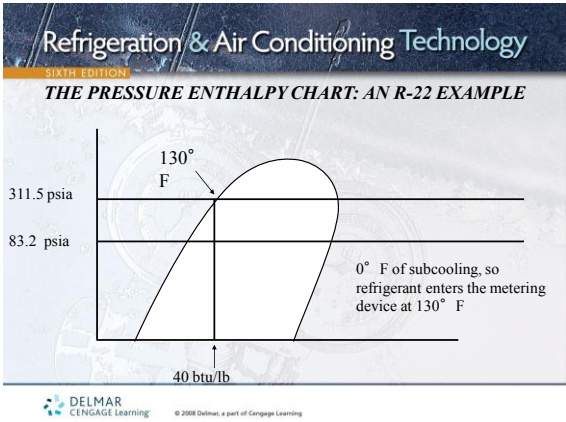
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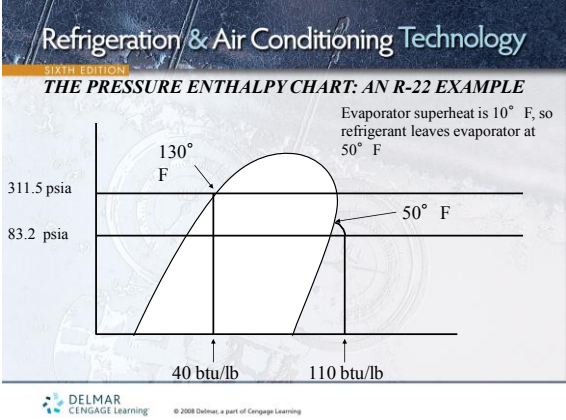
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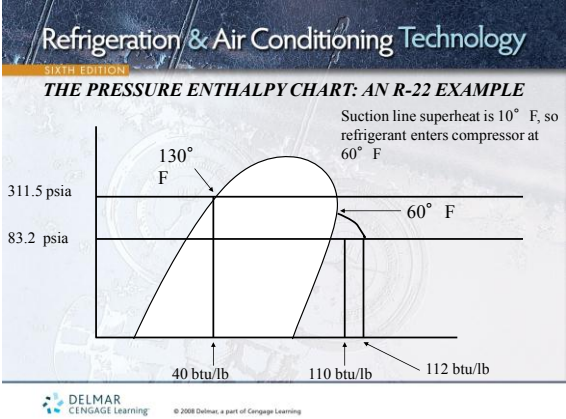
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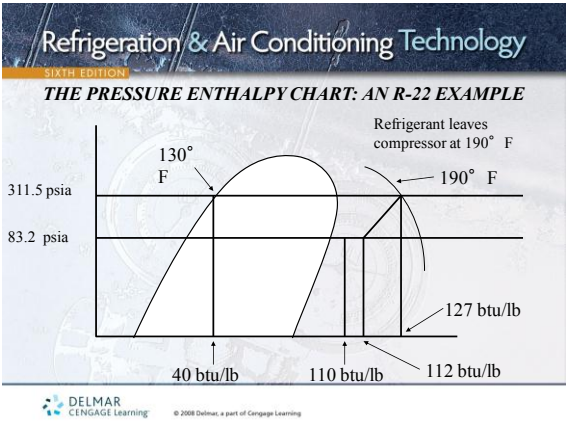
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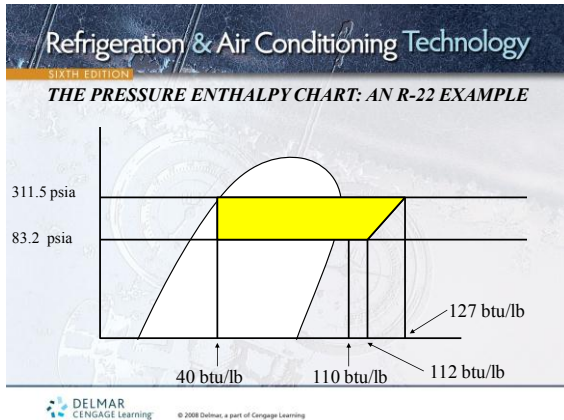
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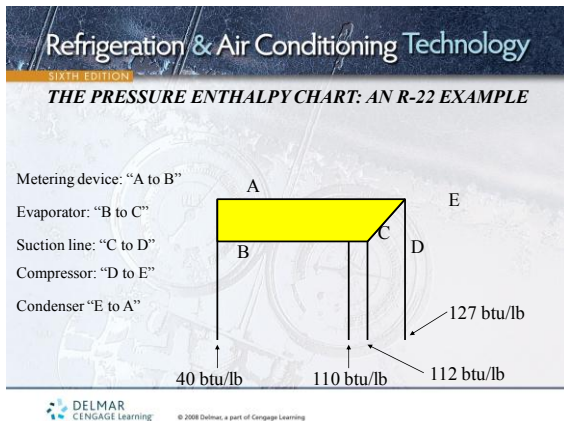
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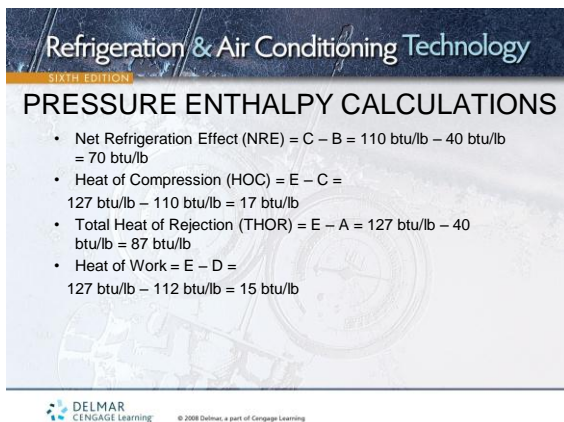
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## UNIT SUMMARY

- Common refrigeration temperature ranges are high, medium and low
- High temperature refrigeration is also referred to as air conditioning or comfort cooling
- Refrigeration is the process of transferring heat from a place where it is objectionable to a place where it makes little or no difference
- Heat flows naturally from warm to cool substances

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## UNIT SUMMARY - 2

- Saturated refrigerants follow a P/T relationship
- One ton of refrigeration is equal to 12,000 btu/hour
- The evaporator is the component that absorbs heat
- The condenser is the component that rejects heat
- The metering device is the component that regulates refrigerant flow to the evaporator
- The compressor creates the pressure difference in the system that allows the refrigerant to flow

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## UNIT SUMMARY - 3

- Superheat is equal to evaporator outlet temperature minus evaporator saturation temperature
- Subcooling is equal to the condenser saturation temperature minus the condenser outlet temperature
- Superheated and subcooled refrigerants do not follow a pressure/temperature relationship
- Modern refrigerants must be safe and detectable
- The pressure enthalpy chart provides a graphical representation of a refrigeration system

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