Key Learning's

• Review of Refrigeration 101
• Basic understanding of more complex components of a refrigeration system
• Overview of more complex mechanical refrigeration systems
• Interaction of the mechanical system with the building
• Equipment planning and location
REFRIGERATION 101 REVIEW
Conduction
Convection
Radiation
Latent Heat
Sensible Heat
HEAT ENERGY
Condenser
Evaporator
Compression
Condenser
Evaporator
Compression
Saturation
Sub-cooled
Superheat
Pressure / Temperature
British Thermal Unit (BTU)
Refrigeration Cycle
Refrigeration Cycle

Enthalpy – measure of the heat energy of a substance.

LPV - Low Pressure Vapor
HPV – High Pressure Vapor
LPL – Low Pressure Liquid
HPL – High Pressure Liquid
SYSTEM MAJOR COMPONENTS OVERVIEW
Select the proper compressor for the appropriate application.
Reciprocating Compressor

- Moving pistons compress refrigerant gas within cylinders.
- On the downstroke, the suction inlet valve is open as low pressure gas refrigerant is drawn into the cylinder.
- When the piston begins its upstroke, the suction inlet valve is closed and pressure increases.
- High pressure gas exits through the discharge port.
Scroll Compressor

- Rotation is critical on scroll compressors.
- An orbiting scroll moves in a circular motion within a second, fixed scroll.
- The gas entering the low pressure inlet is pressurized into continuously smaller areas until it exits through the discharge line.
Intake: the vapor passes through the inlet and into the void which is wide open at the suction end.

Compression: as the rotors contra-rotate, the inlet void closes, the volume is reduced and the pressure increases.

Discharge: compression is completed, final pressure achieved and the vapor is discharged.
Round Tube Plate Fin (RTPF) Air Cooled Condenser

- Coil comprised of:
  - copper tubes to transport refrigerant
  - aluminum fins to increase heat transfer capability
- Fans pull ambient air across coil section
- Heat is rejected to atmosphere
- Refrigerant changes from superheated vapor to sub-cooled liquid
MicroChannel Air Cooled Condenser

- Same operation as RTPF air cooled condenser
- Coil comprised of:
  - flattened aluminum tube with narrow channels
  - aluminum fins in between
- Reduced refrigerant charge
- Smaller size with less weight
Evaporative Cooled Condenser

- Copper tubes transport refrigerant through coil slab
- **Ambient air** blown over coils
- **Water** from a sump is sprayed over the coils to increase heat removal
- Allows the condensing temperature to approach the wet bulb (WB) temperature of the ambient air versus the dry bulb (DB) temperature, which is normally higher.
- Increases system efficiency
Dry Fluid Cooler / Plate-to-Plate Condenser

- Fan cooled coil assembly
- Draws *ambient air* across coil slab to remove heat from *glycol mixture*
- Glycol mixture used as condenser fluid for refrigeration system
- Refrigeration system uses heat exchanger (plate-to-plate shown) to condense compressor discharge gas
  - Located near compressors
Hybrid Fluid Cooler / Condenser

• Uses RTPF coil or microchannel coil
• Equipped with pre-cooling pads to cool incoming ambient air with water that is distributed over the cooling pads
• Air is drawn through the cooling pads and the heat exchangers
• Increases system efficiency
1. Liquid refrigerant passes through expansion valve
   a. Pressure is reduced to “evaporator pressure”
   b. Temperature drops to “saturated suction temperature”
   c. Some liquid is vaporized

2. Refrigerant passes through evaporator
   a. Remaining refrigerant “boils”
   b. Heat is absorbed from inlet air

Display Case Operation (DX)

- Expansion Valve
- Display Case
- Evaporator
- Solenoid Valve
- 70% Liquid 30% Vapor Mix
- "Cold" Discharge Air
- "Warm" Inlet Air
- Return Gas To Compressor
- Liquid Refrigerant From Condenser
1. Cold fluid (Glycol or CO\textsubscript{2}) passes through Balancing Valve (when required)
   - Flow is metered to the case requirements

2. Refrigerant passes through heat exchanger
   - Cold liquid absorbs heat from the inlet air
   - Liquid increases in temperature
     - Glycol does not “boil”
     - CO\textsubscript{2} partially “boils” – two phase mixture

“Warm” fluid to Chiller/Pump Station

“Cold” fluid from Chiller/Pump Station
Display Case Equipment

- Reduces the temperature of the air passing through it (sensible heat)
- Removes humidity (latent heat)
- Low pressure liquid refrigerant is boiled off into low pressure vapor
- Proper airflow though the evaporator coil is critical to its function
- Moisture from ambient air freezes on coil tubes. This frost or ice prevents proper air flow across the coil and air curtain velocities.
- Defrost is the removal of frost or ice from an evaporator coil
  - Off time – MT Coils
  - Electric – LT / MT Coils
  - Hot Gas – LT / MT Coils
  - Cool Gas – LT / MT Coils
  - Warm Fluid – MT Glycol Coils

\*LT – Low temperature evaporator <= 0 F \*MT – Medium temperature evaporator <= 32 F
Case Temperature Control

- **Expansion Valve (EV)**
  - Regulates *refrigerant flow*
  - Maintains superheat at the evaporator outlet

- **Evaporator Pressure Regulator (EPR)**
  - Maintain accurate *display case pressure* and temperature
  - Allows multiple evaporator systems to operate at different temperatures when piped to a common suction group
SYSTEM TYPES
**DX System Operation**

- **LT Compressor**
  - Cold Gas (≈35°F)

- **MT Compressor**
  - Hot Gas (≈250°F)

- **Condenser**
  - Warm Liquid (≈105°F)

- **R404A**
- **EEV**
  - 70% Liquid 30% Gas Mix (15°F)

- **TXV**
  - 70% Liquid 30% Gas Mix (15°F)

**DX – Direct Expansion refrigeration system**
DX Condensing Unit Equipment

- Warm Liquid (≈105°F)
- Cold Gas (≈55°F)
- Medium Temperature
- Low Temperature

Installed in:
- machine rooms
- outside slab
- rooftops
Low Temperature

Medium Temperature

Hot Gas

(≈250°F)

Warm Liquid

(≈105°F)

Cold Gas

(≈55°F)

Cold Gas

(≈35°F)

DX Rack Equipment (Circuit Piping)

Installed in:

• machine rooms
• mezzanines
• outside slab
• rooftops
TYPICAL LINE CIRCUIT LAYOUT
DX Rack Equipment (Loop Piping)

- **Hot Gas** (≈250°F)
- **Warm Liquid** (≈105°F)
- **Cold Gas** (≈55°F)
- **Low Temperature**
- **Medium Temperature**

Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops

Lower refrigerant charge than circuit piping
Distributed DX Equipment (Loop)

- Low Temperature
  - SST (-30°F)
  - Cold Gas (≈55°F)

- Medium Temperature
  - SST (-11°F)

- High Temperature
  - Warm Liquid (≈105°F)
  - Hot Gas (≈250°F)

**Features**
- Low charge
- Reduced leaks
- Less copper
- Energy efficient

**Installed in:**
- Back hallways
- Above walk-ins
- Rooftops
- Under racking
- Etc

*Distributed* – Multiple small compressor units located close to their loads throughout the store.
Secondary Glycol System Operation

* MT Only

- Hot Gas (≈250°F)
- Cold Gas (≈55°F)
- Cold Glycol (+20°F)
- Warm Glycol (+30°F)
- Warm Liquid (≈105°F)

**R404A**

- Condenser
- Compressor
- TXV
- Heat Exchanger
- Glycol Pump
- Circuit Setter
- Cases

**Secondary** – Intermediate medium for heat transfer between cooling load and refrigerant
Secondary Glycol Equipment (Loop)

- Low refrigerant charge
- Reduced leaks
- Less Copper

Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops

* Can also be applied with distributed technology
Secondary CO₂ System Operation

* LT and MT

- Hot Gas (≈250°F)
- Cold Gas (≈55°F)
- Warm Liquid (≈105°F)
- Cold Gas (≈55°F)
- 100% Liquid CO₂ Mix (MT = +20°F) (LT = -20°F)
- 50/50% Liquid/Vapor CO₂ Mix (MT = +20°F) (LT = -20°F)
- 70% Liquid 30% Gas Mix (MT = 15°F) (LT = -25°F)
- R404A
- Compressor
- Condenser
- TXV
- Heat Exchanger
- CO₂ Pump
- Solenoid Valve

Case

CO₂
Secondary CO₂ Equipment (Loop)

- Low refrigerant charge
- Reduced leaks
- less copper
- Uses natural CO₂

Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops

Diagram:
- Hot Gas (≈250°F)
- Warm Liquid (≈105°F)
- Cold Gas (≈35°F)
- Liquid CO₂ (-20°F)
- Wet Vapor CO₂ (+20°F)
- Medium Temperature

- Low Temperature
Cascade CO₂ DX System Operation

* LT Only

- **Condenser**
  - Hot Gas (≈250°F)
- **Compressor**
  - Cold Gas (≈55°F)
- **R404A**
  - Warm Liquid (≈105°F)
- **TXV**
  - 70% Liquid 30% Gas Mix (20°F)
- **Cascade Heat Exchanger**
  - 100% Liquid (≈25°F)
  - CO₂
- **EEV**
  - 70% Liquid 30% Gas Mix (≈35°F)
  - 70% Liquid 30% Gas Mix (≈20°F)
- **CO₂ Compressor**
  - Hot Gas (≈170°F)
- **Case**
  - Cold Gas

**Cascade** – Two independent refrigeration systems in series sharing a common heat exchanger
Cascade CO$_2$ DX Equipment

- Cold Liquid CO$_2$ (+25°F)
- Cold CO$_2$ Gas (+35°F)
- Hot Gas (~250°F)
- Cold Gas (~55°F)
- Warm Liquid (~105°F)

Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops

- Low refrigerant charge
- Reduced leaks
- less copper
- Uses natural CO$_2$
Ammonia (NH3) Primary System

- **Primary Refrigeration Enclosure**
  - Ammonia scrubber
  - Ammonia compressors
  - Ammonia Receiver
  - CO2 Heat Exchanger

- **Primary Refrigeration Loop**

- Primarily used in industrial application
- Typically used with secondary systems
  - Example range of operation (-60°F to +60°F)
- Displaces use of HFC’s
- Can not be used with copper
- Use of water system for scrubbing in case of leak

- Low refrigerant charge
- Reduced leaks
- Natural refrigerant
SYSTEM & BUILDING INTERACTION
Water Heat Reclaim

Heat Reclaim

- Uses available compressor heat to heat building water or air rather than rejecting to atmosphere
- Good source for air reheat or dehumidification
- Increases refrigerant charge
Air Heat Reclaim

Cool Moist Air

Cool / Warm Dry Air

Diagram showing the processes involved in air heat reclaim.
Split Condenser

- Condenser sized with two parallel coils (50% - 50%)
- In Winter operation, 50% of condenser is disabled
- Reduces capacity of condenser for proper system control in cold climates
- Controlled by ambient temp sensor
  - 25% - 50% - 50% split is also available
Heat Reclaim & Split Condenser

* Water reclaim shown
** Can substitute with air if desired
Suction groups
• Manages multiple compressor racks
• Optimizes compressor cycling and energy savings

Microprocessor Controller
• Central point of equipment control and monitoring
• Increases equipment life and energy with logical control algorithms
• Allows equipment monitoring, alarming and optimization

Condensers
• Enhances condenser performance

Controller boards
• Expandable I/O system
• Allows for multiple control and monitoring points

Refrigerant leak detectors
• Immediate notification when leak occurs
• Program multiple set points

Circuits/display cases
• Flexible control options to choose from
• Supports multiples of cases and case types
Tools Used by Engineers / Designers

ANALYSIS & COMPARISONS
Energy Analysis

- **Energy Efficiency Ratio (EER)**
  - Btu/hour per watt
- **Coefficient of Performance (COP)**
  - Unitless
- The amount of cooling divided by the power needed to do the cooling
- A higher value is better
  - it means less energy is used to do a given amount of cooling
- EER and COP depend on many factors
  - evaporating temperature
  - condensing temperature
  - size of condenser
  - type of compressor
  - etc

**EER is heavily influenced by ambient temp:**

<table>
<thead>
<tr>
<th>Hot day</th>
<th>Cold day</th>
</tr>
</thead>
<tbody>
<tr>
<td>COP = 2</td>
<td>COP = 5</td>
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<tr>
<td>EER = 7 Btu/hr/watt</td>
<td>EER = 17 Btu/hr/watt</td>
</tr>
</tbody>
</table>

Energy use is less than half on cold days
Ambient Temperature Bin Hours

Dry Bulb BIN Hour Comparison

Wet Bulb BIN Hour Comparison
## Technology Comparison

<table>
<thead>
<tr>
<th>Approach</th>
<th>Central DX</th>
<th>Distributed DX</th>
<th>Distributed Glycol Secondary</th>
<th>Central Glycol Secondary</th>
<th>Liquid Recirc CO₂</th>
<th>Cascade CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment 1&lt;sup&gt;st&lt;/sup&gt; Cost</td>
<td>Baseline</td>
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<td>Energy Efficiency</td>
<td>Baseline</td>
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<td>Refrigerant Charge</td>
<td>Baseline</td>
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<td>+</td>
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<tr>
<td>Total Cost of Ownership</td>
<td>Baseline</td>
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<tr>
<td>Carbon Footprint</td>
<td>Baseline</td>
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<tr>
<td>Service and Complexity</td>
<td>Baseline</td>
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Better than Baseline
Worse than Baseline
<table>
<thead>
<tr>
<th>System Type</th>
<th>Possible Level</th>
<th>Attainable</th>
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</thead>
<tbody>
<tr>
<td>Distributed</td>
<td>Silver when air-cooled</td>
<td>Gold when air-cooled with microchannel</td>
</tr>
<tr>
<td>Secondary Distributed</td>
<td>Gold when air-cooled condenser</td>
<td>Platinum when water-cooled</td>
</tr>
<tr>
<td>MT Secondary Glycol</td>
<td>Silver with centralized LT DX</td>
<td>Gold with other advanced LT</td>
</tr>
<tr>
<td>Secondary CO₂</td>
<td>Gold when used for both LT &amp; MT Loads</td>
<td></td>
</tr>
<tr>
<td>LT CO₂ Cascade</td>
<td>Gold when combined with MT secondary glycol or secondary CO₂ MT</td>
<td></td>
</tr>
<tr>
<td>MT Glycol Compact Chiller</td>
<td>Platinum when water cooled and combined with LT CO₂</td>
<td></td>
</tr>
</tbody>
</table>

Application of any system type does not guarantee certification ability. Proper planning, equipment selection, application, placement, and refrigerant are required.
Risk Increases Significantly w/ Product Temp

- Salmonella
- Listeria
- E Coli on Beef

Note: Y axis is 1000's of colony forming units per gram. It only takes < 100 cells to cause illness.

Why refrigeration is important - for the preservation and distribution of food...
Thank you for your attention!

Questions?

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