Refrigeration 201

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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
Refrigeration Cycle

Enthalpy – measure of the heat energy of a substance.
SYSTEM MAJOR COMPONENTS OVERVIEW
Select the proper compressor for the appropriate application.
• **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.
Screw Compressor

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
Display Case Operation (DX)

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 (Secondary)

1. Cold fluid (Glycol or CO₂) 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”
     - CO₂ 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)

- **EEV**
  - 70% Liquid 30% Gas Mix (-25°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)

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

DX Rack Equipment (Circuit Piping)
DX Rack Equipment (Loop Piping)

- **Hot Gas** (≈250°F)
- **Warm Liquid** (≈105°F)
- **Cold Gas** (≈35°F)
- **Cold Gas** (≈55°F)

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

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

- Low Temperature
  - SST (~-11°F)
  - Cold Gas (~55°F)
  - Medium Temperature
  - Warm Liquid (~105°F)
  - Hot Gas (~250°F)
  - Distributed – Multiple small compressor units located close to their loads throughout the store

- Installed in:
  - back hallways
  - above walk-ins
  - rooftops
  - under racking
  - etc

- • low charge
  • reduced leaks
  • less copper
  • energy efficient
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)
- 70% Liquid 30% Gas Mix (15°F)

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

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

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)
- 70% Liquid 30% Gas Mix (MT = 15°F) (LT = -25°F)
- 100% Liquid CO₂ (MT = +20°F) (LT = -20°F)
- 50/50% Liquid/Vapor CO₂ Mix (MT = +20°F) (LT = -20°F)
- R404A
- Compressor
- Condenser
- TXV
- CO₂ Pump
- Heat Exchanger
- Solenoid Valve
- Case
Secondary CO₂ Equipment (Loop)

- **Low Temperature**
  - Liquid CO₂ (-20°F)
  - Wet Vapor CO₂ (+20°F)

- **Medium Temperature**
  - Warm Liquid (≈105°F)
  - Cold Gas (≈35°F)

- **High Temperature**
  - Hot Gas (≈250°F)

- **Wet Vapor CO₂ (+20°F)**

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

- **Bullet Points:**
  - Low refrigerant charge
  - Reduced leaks
  - less copper
  - Uses natural CO₂
Cascade CO₂ DX System Operation

* LT Only

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

- **Warm Liquid** ($\approx 105^\circ$F)
- **Cold Gas** ($\approx 55^\circ$F)
- **Hot Gas** ($\approx 250^\circ$F)
- **Cold Liquid CO$_2$** (+25$^\circ$F)
- **Cold CO$_2$ Gas** (+35$^\circ$F)

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

- Low refrigerant charge
- Reduced leaks
- less copper
- Uses natural CO$_2$

*Loop Piping Shown*
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
Cold Water 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

Heat Reclaim

Water Heat Reclaim Diverting Valve
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

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

Circuits/display cases
• Flexible control options to choose from
• Supports multiples of cases and case types

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

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

Condensers
• Enhances condenser performance
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>
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<tbody>
<tr>
<td><strong>COP = 2</strong></td>
<td><strong>COP = 5</strong></td>
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<tr>
<td><strong>EER = 7 Btu/hr/watt</strong></td>
<td><strong>EER = 17 Btu/hr/watt</strong></td>
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</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>
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<tbody>
<tr>
<td>Equipment 1(^\text{st}) Cost</td>
<td>Baseline</td>
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<td>Energy Efficiency</td>
<td>Baseline</td>
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<tr>
<td>Refrigerant Charge</td>
<td>Baseline</td>
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<tr>
<td>Total Cost of Ownership</td>
<td>Baseline</td>
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<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
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<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>
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<tr>
<td>Secondary Distributed</td>
<td>Gold when air-cooled condenser</td>
<td>Platinum when water-cooled</td>
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<tr>
<td>MT Secondary Glycol</td>
<td>Silver with centralized LT DX</td>
<td>Gold with other advanced LT</td>
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<tr>
<td>Secondary CO₂</td>
<td>Gold when used for both LT &amp; MT Loads</td>
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<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>
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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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