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Introduction to CO2 Cascade Systems

June 21th, 2012
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Today’s speaker.........
Rusty Walker is a Senior Corporate Trainer with Hill PHOENIX Learning Center. He has more than 25 years of experience in the industry. He conducts many courses and seminars throughout the country on refrigeration systems, power systems, display cases, and walk-in coolers, and is well versed in most aspects of the industry. An avid music and baseball enthusiast, Rusty often sets the tone for his courses with a lively tune.
## Useful Definitions

<table>
<thead>
<tr>
<th><strong>Direct Expansion</strong></th>
<th>A refrigeration system that includes a compressor, condenser, evaporator coil, and an expansion device</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Refrigerant</strong></td>
<td>A fluid used to lower the temperature of a secondary coolant (i.e. R-22, R-404a, R-507, R-410A, R-717, etc...)</td>
</tr>
<tr>
<td><strong>Secondary Coolant</strong></td>
<td>(a.k.a Secondary Refrigerant, Secondary Fluid) A fluid used to transfer heat from a heat source (i.e. refrigerated space) to a primary refrigerant.</td>
</tr>
<tr>
<td><strong>Single-Phase Secondary Coolant</strong></td>
<td>(a.k.a Secondary Refrigerant, Secondary Fluid) A fluid used to transfer heat from a heat source (i.e. refrigerated space) to a primary refrigerant.</td>
</tr>
<tr>
<td><strong>Two-Phase Secondary Coolant</strong></td>
<td>A secondary fluid which absorbs heat by means of latent heat transfer resulting in a change in phase (i.e. carbon dioxide, ice-slurries)</td>
</tr>
</tbody>
</table>
Useful Definitions

**Cascade System**
A system having two (or more) refrigerant circuits, each with a compressor, condenser and evaporator, where the evaporator of one circuit cools the condenser of another circuit.

**Upper Cascade**
The refrigerant circuit in a cascade system that cools the condenser of the lower-cascade and transfers the heat to a heat sink, typically outdoor ambient.

**Lower Cascade**
The refrigerant circuit in a cascade system that removes heat from a refrigerated load and transfers the heat to the upper-cascade.
Subcritical vs. Transcritical

- **Subcritical** - CO2 systems where the pressure of the CO2 is maintained well below the critical pressure of 87°F / ~1055 psig.

- Operating pressures for subcritical systems are slightly higher than those in conventional direct-expansion systems but are similar to those seen in air-conditioning applications using R-410A.

- **Transcritical** - CO2 systems that are designed to operate at pressures above the critical pressure, above 1055 psig.
Triple Point vs. Critical Point

- **Triple Point**
  - Liquid CO2 below 60PSIG changes to Dry Ice

- **Critical Point**
  - 87°F = 1055 psig
  - No longer able to distinguish between liquid and vapor.
  - An undefined gas.
  - Only found in a Transcritical system.
Carbon Dioxide is used as a secondary coolant or a Direct Expansion Refrigerant

Carbon Dioxide = CO$_2$ = R-744
Types of CO₂ Cascade Systems

- Secondary-Low & Medium Temperature
- Cascade (Sub-critical) Low Temperature
- Transcritical Medium Temperature
Supercritical Fluid

Supercritical Region

Subcritical Region

1070 psia

$T_{\text{SAT}}=87^\circ \text{F}$

SNLTX2 Lower CASCADE

CO$_2$ Cascade System Types
System Typical Operating Pressures

Low-Side
Typ. Operating Suction 200-275 psig

High-Side
Typ. Operating Discharge 400-500 psig

Low Suction: <200 psig
Normal Operating Suction: 200-275 psig
High Suction: >275 psig

Low Discharge: <400 psig
Normal Operating Discharge: 400-500 psig
High Discharge: >500 psig
Pressure Regulating Relief Valve: 560 psig
Main Pressure Relief Valve: 625 psig

CO2 Low-Side Suction (psig)
CO2 High-Side Discharge, Separator (psig)
Low Temperature – CO$_2$ Cascade System
Low Temperature – CO$_2$ Cascade System

Advancing CO$_2$ technology will lead to better energy vs. traditional DX systems

- Low temperature system that compresses CO$_2$ to an intermediate pressure (425 psig = 25 degF).
- Even smaller copper piping than CO$_2$ Secondary.
- Uses components easily available in the aftermarket.
- Better heat transfer properties of CO$_2$ and better TD’s lead to higher compressor SST and better energy efficiency.
- Widely available, low cost natural refrigerant with nearly zero global warming potential.
Utilizes CO₂ as a direct expansion cascade refrigerant for the low-temperature system.
Uses efficient and quiet CO₂ subcritical compressors.
Evaporators designed specifically for use with CO₂ as a direct expansion refrigerant.
Display cases and freezers are equipped with EEV’s for steady, automatic control of superheat leaving the evaporators.
CO₂ Compressors:

- Typical 3-5 Units in Parallel
- Types Available:
  - Reciprocating – Bitzer
  - Scroll – Emerson
- Accessories:
  - High Pressure Switch
  - Low Pressure Switch
- Capacity Control:
  - VS on Reciprocating
  - Digital Scroll
- UL for Both Models

Low Temperature – CO₂ Cascade System
Low Temperature – CO₂ Cascade System

Oil Separator:
- Removes Most of the Oil Carried Over from Compression
- Accessories:
  - Oil Filter
  - Sight Glass
Condenser-Evaporator:
- Condenses CO2 Discharge Gas into Liquid
- Evaporates Primary HFC Refrigerant
- Typically 2-4 Units in Parallel
CO2 Receiver:

- Compensates for Level Fluctuations during Defrost
- Can be UL or ASME Vessel
- Accessories:
  - Sight Glasses
  - Dual Pressure Relief Valve
  - Liquid Level Switch
  - Liquid Filter-Drier
  - Charging Valve

Low Temperature – CO₂ Cascade System
Evaporator Electronic Expansion Valves:
• Regulates flow of CO2 into Coil to Maintain Desired Superheat
• Stepper or PulseValve from
• Accessories:
  • Pressure Transducer
  • Temperature Probe
Evaporator Coils:
- Evaporates CO2 to Refrigerate Case or Walk-In
- Hill PHOENIX Display Cases
- Heatcraft's RPD Unit-Cooler
- Same Cross-Section as HFC DX but Re-Circuited for CO2
- Electric Defrost
- Accessories:
  - SLHE
  - Solenoid from Sporlan (possibly one per circuit, if needed)
Low Temperature – \( \text{CO}_2 \) Cascade System

**Upper-Cascade:**
- Refrigerates Condenser of Lower-Cascade
- Can Refrigerate other MT Loads Also (either DX or Secondary Coolant)
- Typical HFC System
Upper-Cascade Systems

- Any refrigerant
- Any compressor
- Any condenser
The Difference Between Secondary & Cascade

- Pumps vs. Compressors
- HFC Rack SST

LT2 - CO₂ Secondary

LTX2 - CO₂ DX Cascade

Med Temp Parallel DX Rack (+15 SST)

Low Temp Parallel DX Rack (-22 SST)
The Difference Between Secondary & Cascade - CO₂ Operating Pressure

LT2 - CO₂ Secondary

LTX2 - CO₂ DX Cascade

Med Temp Parallel DX Rack (+15 SST)

Low Temp Parallel DX Rack (-22 SST)
The Difference Between Secondary & Cascade Case Control Valves

LT2 - CO₂ Secondary

LTX2 - CO₂ DX Cascade
LT Cascade Advantages

• Smaller line sizes than HFC DX
• Lower energy consumption for CO2 Cascade systems
• Better heat transfer on CO2 side for higher compressor SST
• Coil TD’s better than DX Systems

HFC DX Discharge Air Temp = -7 deg F
LTX2 Discharge Air Temp = -10 deg F
LTX2 Coil Temp = -15 deg F
LTX2 Compressor SST = -16 deg F
HFC DX Coil Temp = -18 deg F
HFC DX Compressor SST = -20 deg F
Questions?