# What’s Hot in Supermarket Refrigeration?

**Energy**
- MT Cases With Doors
- LED Lighting
- Low Condensing
- ECM Fan Motors for Condenser and Case Fans

**Environment**
- EPA Proposal to Delist R404A
- R-22 Retrofits
- Natural Refrigerants
- LCCP Analysis

**Equipment**
- Mechanical to Electronic Control
- Connected Devices/Mobile
- Technician Shortage
- ASHRAE Commissioning Guide

**Economics**
- Information Age (Traceable, Feedback)
- Millennials (e-commerce, Local, Organic)
- “Smaller” Format Stores
- Foodservice Integration

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E360
$35k/Year Energy Savings per Store by Implementing Low Condensing

**Boston Temperature Profile**

- **Opportunity for Savings**
- **Hours/Yr**
- **% Time Below 60 °F**
  - 90%
  - 80%
  - 70%
  - 50%
  - 20%

**Compressor Performance**

- **Condensing Temperature**
  - 50°F
  - 70°F
  - 90°F
  - 110°F
- **Compression Efficiency**
  - ≈20% Increase in Compressor Efficiency for a 10° Drop in Condensing Temperature

**Typical Boston Supermarket**

- **50 Min Cond**
  - 35%
  - $35K Savings
- **70 Min Cond**
  - 14%
- **90 Min Cond**

**Total Annual Cost (@ $0.9/kWh)**

- $0K
- $50K
- $100K
- $150K
CoreSense Provides Step Change in System Reliability and Troubleshooting

Compressor Protection & Control
- Discharge Temperature Protection
- Digital Modulation Control
- Liquid Injection Control via Electronic Stepper Valve
- Phase Monitoring, Short Cycling, Welded Contactor & Proofing Through Current Sensing
- 15 LED Alarm Codes
- Remote Communications (Modbus)

Remote Communications & Reset
- E2 Facility Management
- Emerson Site Manager
- Alarm Status
- Discharge Temp
- Run Time/ Cycle Count
- Model & Serial #
- Amps
- 7-Day Alarm History
Convenience, Fresh, Specialty and e-Commerce Shake up Grocery Landscape

Wal-Mart Hopes To Boost Sales By Opening Convenience Stores

Target to Open ‘Smallest Location Ever’
Test store will feature “everyday essentials,” including grab-and-go sandwiches

Walmart U.S. accelerates small store growth
Expansion program doubles initial forecast

US organic food market to grow 14% from 2013-18

Aldi to Boost Its Number of U.S. Stores by 50%

Lidl postpones plan to open U.S. stores to 2018

Dollar General and Family Dollar the New Small Format Grocery Stores?

Ethnic Supermarket Industry Expands

AmazonFresh groceries arrive in Brooklyn
Energy Usage Will Become Primary Source for CO₂ Emissions

Boston, MA LCCP Analysis

- CO₂ Booster
  - 50°F Min Cond; EXV
  - 50°F Min Cond; EXV
  - 50°F Min Cond; EXV
  - Annual Energy: -15.3% / LCCP: -62.9%

- Secondary – 300 GWP
  - 50°F Min Cond; EXV
  - 50°F Min Cond; EXV
  - Annual Energy: -17.2% / LCCP: -63.7%

- Cascase – 300 GWP MT
  - 50°F Min Cond; EXV
  - Annual Energy: -12.5% / LCCP: -61.6%

- 1500 GWP DX
  - 50°F Min Cond; EXV
  - 70°F Min Cond; TXV
  - Annual Energy: -14.8% / LCCP: -44.1%

- 1500 GWP DX
  - 70°F Min Cond; TXV
  - Annual Energy: -3.4% / LCCP: -39.1%

- R404A DX
  - Base LT Indirect
  - Base MT Indirect
  - Base LT Direct
  - Base MT Direct

LT = Low Temperature
MT = Medium Temperature
DX = Direct Expansion
LCCP = Life Cycle Climate Performance
Understanding Assumptions Critical for “Apples to Apples” Comparisons

**Minimum Condensing Temperature**
- Condensing Temperature (F) vs. Energy Savings
- 90F Baseline

**Compressor Superheat**
- Compressor Superheat (F) vs. Energy Savings
- 50F Baseline

**Subcooling**
- Subcooling (F) vs. Energy Savings
- OF Baseline

**Temperature Differential (TD)**
- Temperature Differential (TD) vs. Energy Savings
- 17LT, 22MT Baseline
Refrigerant Change Being Driven by Regulations and Voluntary Actions

**Regulations**

- **Montreal Protocol**
  - Targets Ozone Depletion (R-22) Signed 1987

- **North American Proposal**
  - Targets CO₂ Emissions (High Global Warming)

**Organizations**

- **United Nations Framework Convention on Climate Change**
- **CCAC**
  - Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants
- **INTERGOVERNMENTAL PANEL ON climate change**

- **California Environmental Protection Agency**
  - Air Resources Board

- **Danish Ministry of the Environment**
  - Environmental Protection Agency
  - HFC Ban & Tax

- **Australian Government**
  - Department of Sustainability, Environment, Water, Population and Communities
  - Carbon Tax

- **European Commission**
  - F-Gas Regulation

- **Ammonia**
  - Everything Natural
Natural Refrigerants Gaining Traction in North American Supermarkets

Leading Edge Field Trials

H-E-B
Austin, TX
R290
Micro-Distributed

Sprouts
Dunwoody, GA
Transcritcal CO₂ Booster

Albertsons
Carpinteria, CA
Ammonia/CO₂ Hybrid

Walgreens
Evanston, IL
Net Zero Store, Geothermal, CO₂

CO₂ Installed Base

Source: Shecco “Guide 2012: Natural Refrigerants for Europe

Source: ATMOsphere America 2014 – Hillphoenix “Market progress..”
General Uses for CO$_2$

- Fire Extinguishers
- Beverage
- Plants
- Solvent
- Modified Atmospheric Packaging
- Refrigeration
Where Does CO₂ (R744) Come From?

- **By-product of:**
  - Fermentation of Ethanol
  - Combustion of Fossil Fuels
  - Liquefaction of Air

- **Naturally Occurring in Wells**

- **The Atmosphere Comprises Approximately 0.04% CO₂ (370 ppm)**

- **Manufacturing Process:**
  - Filtration, Drying and Purification
    - Results in Different Grades of CO₂ for Different Applications:
      - Industrial Grade, 99.5%
      - Bone Dry, 99.8%
      - Anaerobic, 99.9%
      - **Coleman Grade, 99.99% (Used in Refrigeration)**
      - Research Grade, 99.999%
      - Ultra Pure, 99.9999%
Benefits of Using CO$_2$ as a Refrigerant

- CO$_2$ is a natural refrigerant with very low global warming potential
  - ODP = 0, GWP = 1
- Non-toxic, Non-flammable
- CO$_2$ is an inexpensive refrigerant compared with HCFCs and HFCs
- CO$_2$ has better heat transfer properties compared to conventional HCFCs and HFCs
- More than 50% reduction in HFC refrigerant charge possible (high volumetric cooling capacity)
- CO$_2$ lines are typically one to two sizes smaller than traditional DX piping systems
- Excellent material compatibility
- System energy performance equivalent or better than traditional HFC systems in cool climates
Basic Considerations When Using CO₂ as a Refrigerant

- The critical point is the condition at which the liquid and gas densities are the same. Above this point distinct liquid and gas phases do not exist.
- The triple point is the condition at which solid, liquid and gas coexist.
- The triple point of carbon dioxide is high (60.6 psi) and the critical point is low (87.8 °F) compared to other refrigerants.

Photo, Courtesy “GreenChill”, Introduction to CO₂ Refrigeration, Feb.9, 2012
# Basic Properties of R744, R404A and R134a Refrigerants

<table>
<thead>
<tr>
<th>Property</th>
<th>R744</th>
<th>R404A</th>
<th>R134a</th>
<th>R407A</th>
<th>R407F</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Temperature at atmospheric pressure</strong></td>
<td>-109.3 °F (-78.5 °C) (Temp of dry ice)</td>
<td>-50.8 °F (-46 °C) (Saturation temp.)</td>
<td>-14.8 °F (-26 °C) (Saturation temp.)</td>
<td>-41.8 °F (-41 °C) (Mid-point saturation temp.)</td>
<td>-45.5 °F (-43 °C) (Mid-point saturation temp.)</td>
</tr>
<tr>
<td><strong>Critical temperature</strong></td>
<td>87.8 °F (31 °C)</td>
<td>161.6 °F (72 °C)</td>
<td>213.8 °F (101 °C)</td>
<td>179.6 °F (82 °C)</td>
<td>181.4 °F (83 °C)</td>
</tr>
<tr>
<td><strong>Critical pressure</strong></td>
<td>1,055 psig (72.8 barg)</td>
<td>503 psig (34.7 barg)</td>
<td>590 psig (40.7 barg)</td>
<td>641 psig (44.2 barg)</td>
<td>674 psig (46.5 barg)</td>
</tr>
<tr>
<td><strong>Triple point pressure</strong></td>
<td>60.6 psig (4.2 barg)</td>
<td>0.44 psig (0.03 bar abs)</td>
<td>0.0734 psig (0.005 bar abs)</td>
<td>0.19 psig (0.013 bar abs)</td>
<td>TBC</td>
</tr>
<tr>
<td><strong>Pressure at a saturated temperature of 20 °C (68 °F)</strong></td>
<td>815 psig (56.2 barg)</td>
<td>144 psig (9.9 barg)</td>
<td>68 psig (4.7 barg)</td>
<td>133 psig (9.2 barg)</td>
<td>139 psig (9.6 barg)</td>
</tr>
<tr>
<td><strong>Global warming potential</strong></td>
<td>1</td>
<td>3922</td>
<td>1430</td>
<td>1990</td>
<td>1824</td>
</tr>
</tbody>
</table>
Pressure — Enthalpy Diagram for CO$_2$
Selecting the Best System: Secondary vs. Cascade vs. Booster
The high stage system (HFC, HC or Ammonia) cools the liquid CO₂ in the secondary circuit like a simple chiller system.
- CO₂ is cooled to 26 °F (275 psig) for the MT load and -13 °F (181 psig) for the LT load.
- The CO₂ is pumped around the load.
- It is volatile, so unlike a conventional secondary fluid such as glycol it does not remain as a liquid. Instead, it partially evaporates.
- It therefore has a significantly greater cooling capacity than other secondary fluids.
- This reduces the pump power and the temperature difference at the heat exchanger.
Selecting the Best System: Secondary vs. Cascade vs. Booster
Typical Retail Cascade (Hybrid) System

- **High-stage (HFC) System:**
  - provides cooling for the medium-temperature load
  - removes the heat from the condensing CO₂ in the low stage at the cascade heat exchanger

- **Low-stage (CO₂) System:**
  - CO₂ condensing temperature is maintained below the critical point
  - CO₂ pressures are similar to R-410A
  - Utilizes CO₂ as a direct expansion refrigerant
  - Uses efficient and quiet CO₂ subcritical compressors
  - CO₂ specific evaporators
  - Electronic expansion valves with EEVs for steady, automatic control of superheat leaving the evaporators
  - All liquid lines must be insulated
Typical Cascade System Operating Pressures

- **CO2 Low-Side Suction (psig)**
  - Normal Operating Suction: 200-275 psig
  - High Suction: >275 psig
  - Low Suction: <200 psig

- **CO2 High-Side Discharge, Separator (psig)**
  - Normal Operating Discharge: 400-500 psig
  - High Discharge: >500 psig

**Low Side (Suction)**
- Typ. Operating Suction: 200–275 psig

**High Side (Discharge and Receiver)**
- Typ. Operating Discharge: 400–500 psig

- **Low-Side Pressure Relief (Recip.):** 350 psig
- **Low-Side Pressure Relief (Scroll):** 475 psig
- **Main Pressure Relief Valve:** 625 psig
- **Pressure Regulating Relief Valve:** 560 psig
- **Low-Side Pressure Relief (Scroll):** 475 psig

Courtesy of “The Green Chill Partnership and Hill Refrigeration”
Selecting the Best System: Secondary vs. Cascade vs. Booster
**CO₂ Booster Refrigeration System in Transcritical Operation**

- CO₂ is circulated in LT and MT sections
- Gas cooler in supercritical mode
- Condenser in subcritical mode
- Three separate sources of suction gas for MT compressors
- LT requires two stages to keep compression ratios low and discharge temperatures from exceeding the oil’s temperature limit
Higher gas density of CO₂ results in smaller compressor displacement with equivalent R404A motor size

- PRV Relief Valves: 66/135 bar (957/1,958 psig) for low/high side
- Max. Operating Pressure = 120 bar (1,740 psig)
- Inverter Release: 25–70 hz
- CoreSense Protection
Improving Efficiency With Adiabatic Condensers / Gas Coolers

Allows subcritical operation for as long as possible as ambient starts to rise.

ADIABATIC PAD

E = Evaporation  B = Bleed-off
F = Fresh water  D = Distribution
P = Pump capacity
CO₂ Booster Refrigeration System
High-Pressure Control

- Helps maintain sub-cooling in condenser when in subcritical mode
- Create pressure drop into the flash tank
- Optimizes COP during transcritical operation
CO₂ Booster Refrigeration System
With Parallel Compression

- Flash gas is compressed by a different compressor
- 8% higher efficiency
- Smaller gas cooler
- By-pass valve remains to manage low load and low condensing conditions
Case controls and EEV (PWM or stepper)

Due to high heat transfer coefficient of CO₂ vs. HFC, if the same HFC rated evaporators are used, greater capacities and lower TD would result with improved efficiency.

Smaller tubing coils can be used to reduce material cost and footprint.
- LT subcritical compressors are same as those used in cascade systems
- Discharges into suction of transcritical

- High side: 43 bar / 630 psig
- Low side: 28 bar / 406 psig
- Low side “PRV” supplied with (34.4 barg) 500 psig
- Oil: RL68HB POE
CO₂ Booster Refrigeration System
Emerson’s Connected Offering

Emerson Offering
- Centralized Controller
- Distributed Controller
- Transcritical Compressors
- Subcritical Compressors, Semi and Scroll
- Oil Level Controls
- Compressor VFD
- Condenser Motor VFD
- High-Pressure Controller
- Bypass Valve Controller
- High-Pressure Valves
- Case Controllers
- Electronic Expansion Valves
- System Protectors
- Pressure Transducers
- Leak Detection
Conclusions

Transcritical systems are usually used in areas where the ambient temperature is generally low (i.e., predominantly below 68 °F to 77 °F), such as northern Europe, Canada and the northern U.S. New system designs and technology are allowing improved efficiency in warmer climates.

Cascade and secondary systems (subcritical CO₂) are usually used in high ambient areas such as southern Europe, the mid- to southern U.S., and much of Central and South America, Asia, Africa and Australia.

The use of transcritical systems in high ambients generally results in low efficiency; hence, cascade or secondary systems are preferred in those areas.
1. Introduction
2. CO₂ Basics and Considerations as a Refrigerant
3. Introduction to R744 Systems
4. R744 System Design
5. R744 Systems — Installation, Commissioning and Service
# System Architectures — Multiple Choices Being Evaluated

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<tr>
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<th>Environment</th>
<th>Equipment</th>
<th>Economics</th>
<th>Future</th>
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<tr>
<td>Centralized DX</td>
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<td><img src="image" alt="Environment" /></td>
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<td>407 → HFO Blend</td>
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<td><img src="image" alt="Environment" /></td>
<td><img src="image" alt="Equipment" /></td>
<td><img src="image" alt="Economics" /></td>
<td>HFO Blend</td>
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<tr>
<td>Sub-critical CO₂ (HFC/CO₂ Cascade)</td>
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<td><img src="image" alt="Equipment" /></td>
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<td>Ammonia/CO₂</td>
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<td>Transcritical CO₂ (CO₂ Booster)</td>
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<td>Micro-Distributed</td>
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Thank You!

Questions?

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