Making Sense of the promising role of new refrigerants.

Webinar Series

Making Sense
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EMERSON
Climate Technologies

Making Sense of Natural Refrigerants

May 20, 2014

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Emerson Climate Technologies

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Agenda

- **New European F-Gas Regulation (April 2014)**
- **Hydrocarbon Refrigerants, Propane, Isobutane**
- **Ammonia Refrigeration, still going strong**
- **CO_2 System Architecture Options**
  - Secondary
  - Cascade
  - Booster Transcritical
- **Summary**

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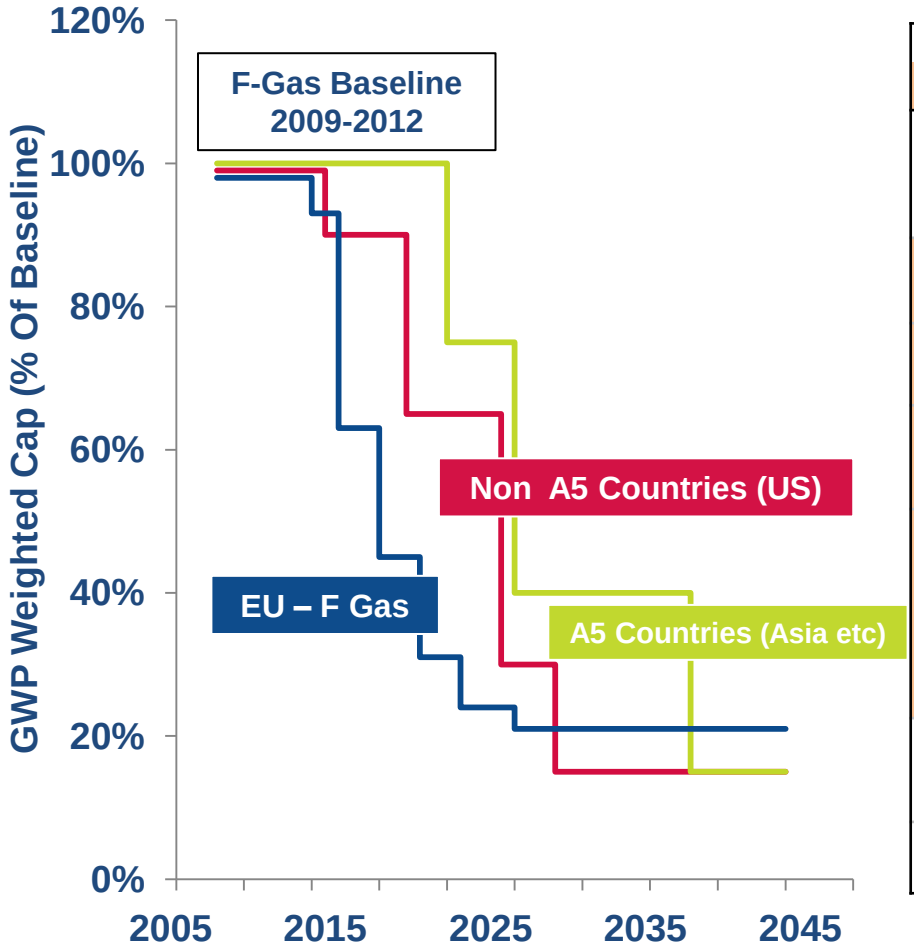
Europe's New F-Gas Phase Down And Bans Goes Into Effect Jan 1, 2015



Service and maintenance ban	GWP	Timing
HFCs	2500	**Jan. 2020**
'Placing on the market' (new equipment) bans		
Domestic refrigerators and freezers	150	**Jan. 2015**
Refrigerators and freezers for commercial use (hermetically sealed systems)	2500	**Jan. 2020**
Refrigerators and freezers for commercial use (hermetically sealed systems)	150	**Jan. 2022**
Stationary refrigeration equipment (except equipment for temperatures below -50 deg C	2500	**Jan. 2020**
Multipack centralized refrigeration systems for commercial use with a capacity of ≥ 40 kW (140 kBTU/hr) (except in the primary refrigerant circuit of cascade systems, where fluorinated greenhouse gases with a GWP of less than 1500 may be used)	150	**Jan. 2022**
Movable room air-conditioning appliances (hermetically sealed equipment which is movable between rooms by the end user)	150	**Jan. 2020**
Single split air-conditioning systems containing < 3 kg	750	**Jan. 2025**

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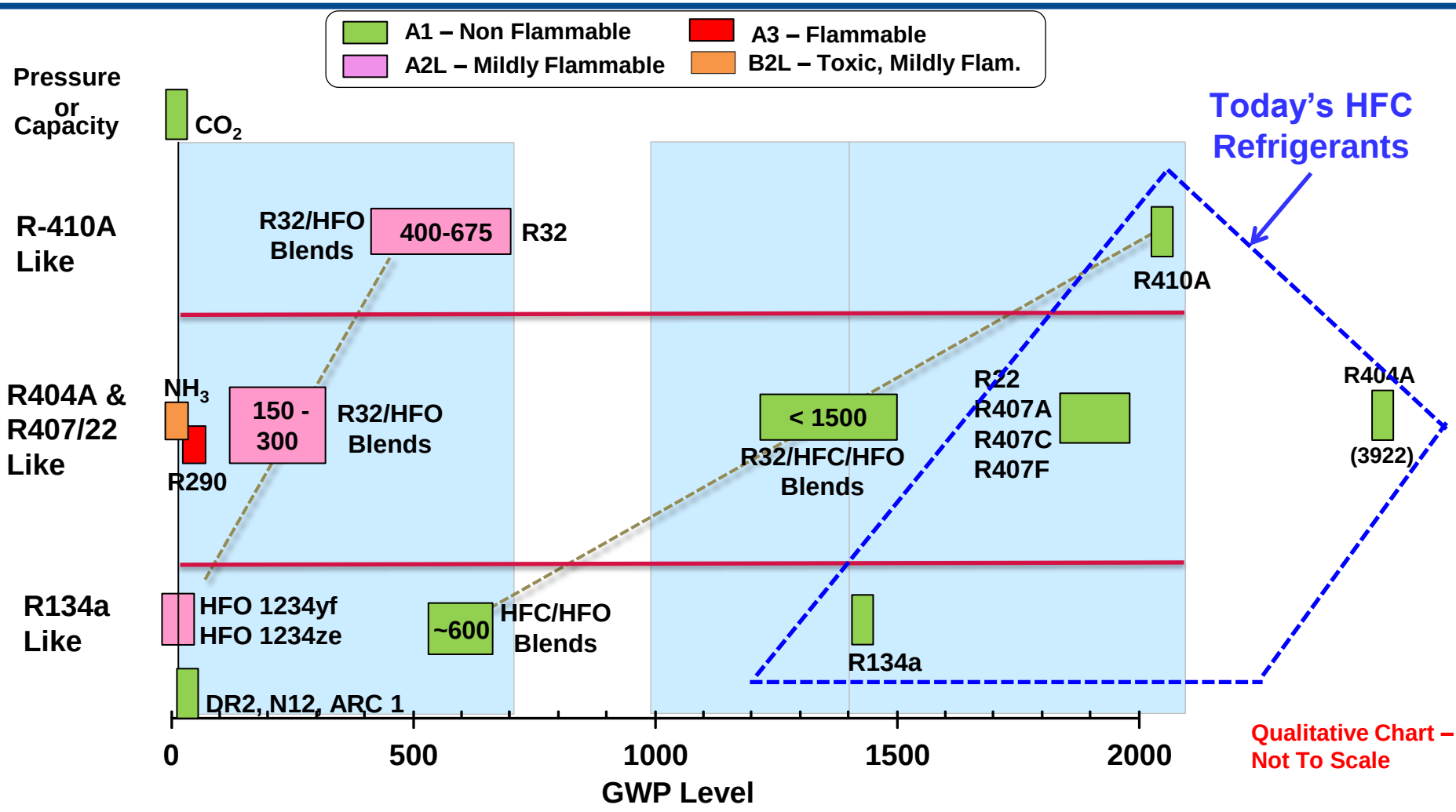
Refrigerant Related Actions In United States And North America

- **US, Canada and Mexico Presenting the North American Proposal Amendment to the Montreal Protocol**
- **US EPA announced two rulemakings for this summer <u>affecting new equipment only</u>**
  - 1st rule: approve new lower GWP fluids, including R32 in specific applications
  - 2nd rule: "change status" of R404A in multiplex supermarket refrigeration systems, R134a in auto AC and reach-in coolers (and foam as well)

Refrigerants Landscape



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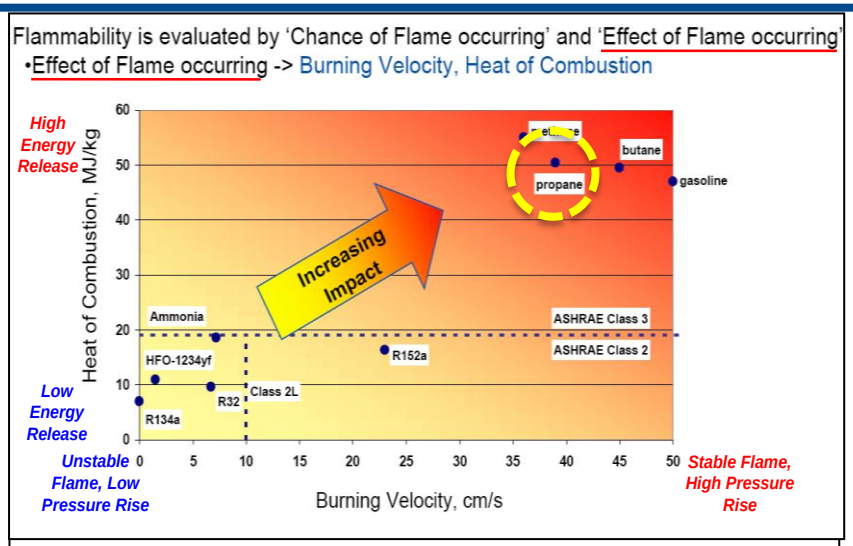
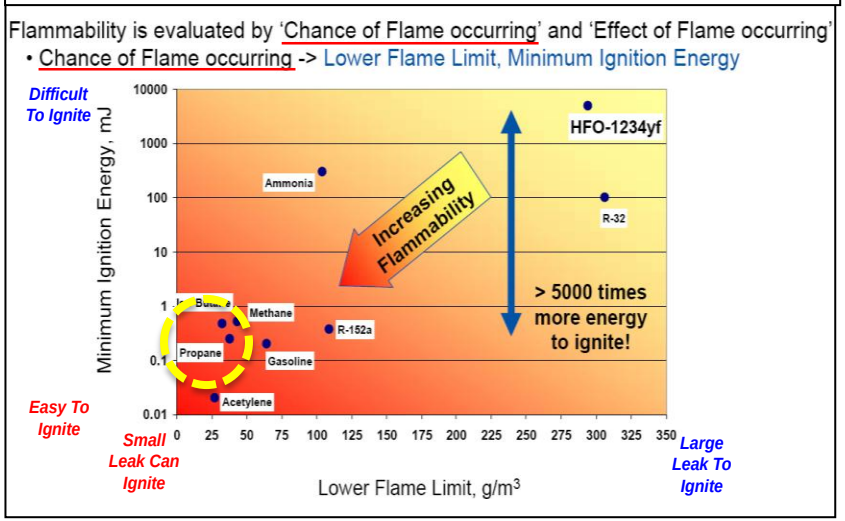
Key Features of Hydrocarbons

R290 (Propane), R600a (Isobutane)

- **A3** Classified , Highly Flammable
- 0 ODP, GWP = 3
- Environmentally benign refrigerants
- Lower discharge temperatures Vs HCFC/HFC, improving the system reliability.
- Reduction in refrigerant charge
  - Compared to R22 and R134a, R290 results in excess of 40% reduction in charge.
  - R290 Pressure/temperature characteristics are similar to R22
- R600a is widely used in domestic applications and many countries
  - 95% of domestic refrigerators in Europe work with R600a, and now Argentina, Brazil, China and other countries in Asia are beginning to adopt R600a in refrigerators and freezers.
  - Its smaller volumetric capacity and higher pressure ratios, limit it to very small capacities.

Propane is Growing in Acceptance Within Constraints of its Flammability





- **Propane (R290) is classified A3, a non-toxic, highly flammable refrigerant by ASHRAE**
- **Current UL Standards for A3 refrigerants allow up to;**
  57 gm(2oz) in household refrigeration
  150 gm(5.3oz) in commercial reach-in refrig
  300 gm (10.6oz) in commercial walk-in refrigeration
- **No AC or heating applications allowed with A3 refrigerants per UL standards; standards under revision now**
- **ISO 5149 and IEC 60335-2-40 Standards allow higher charge limits for all applications.**

Propane applications will grow, especially in the smaller sizes; safety in service will be important for adoption

Making Sense

R290 vs R404A – A Medium Temperature Comparison

Medium Temperature: 20°F

Property	R290	R404A	R290/R404A
Suction Density	0.53 lb/ft^3	1.53 lb/ft^3	
Evap Latent Heat	165.2 Btu/lb	73.8 Btu/lb	
Evap Capacity*	87.3 Btu/ft^3	112.9 Btu/ft^3	77%

*** Suction Density x Evap Latent Heat**

Medium Temp 50 Hz Models					
Priority	Propane Model	Propane Capacity	R404A Reference	R404A Capacity	Voltage
NA	ASE17C4U-IAZ	1377	NA	NA	220/240
NA	ASE18C4U-IAZ	1490	ASE19C3E-IAZ	1590	220/240
NA	ASE24C4U-IAZ	2025	ASE26C4E-IAZ	2250	220/240
NA	ASE32C4U-IAZ	2484	ASE32C3E-CAZ	2760	220/240
NA	RST37C1U-IAZ	3060	RST40C1E-CAB	3060	220/240
NA	RST44C1U-CAZ	3692	RST45C1E-CAB	3550	220/240
NA	RST53C1U-CAZ	4284	RST55C1E-CAB	4200	220/240
NA	RST58C1U-CAZ	4859	RST61C1E-CAZ	5115	220/240

Shown For Example Only - Contact Emerson Climate Technologies, Inc. For More Information

Emerson's R290 Compressor

For same displacement, R290 has less capacity – most shortfall made up in system due to better heat transfer resulting in higher saturated suction

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Early Adopters of Natural Refrigerants

Propane R290
Isobutane R600a
CO2 R744

http://www.unep.fr/bangkoktechconference/docs/VIII-3%20Claudia%20Becker.pdf

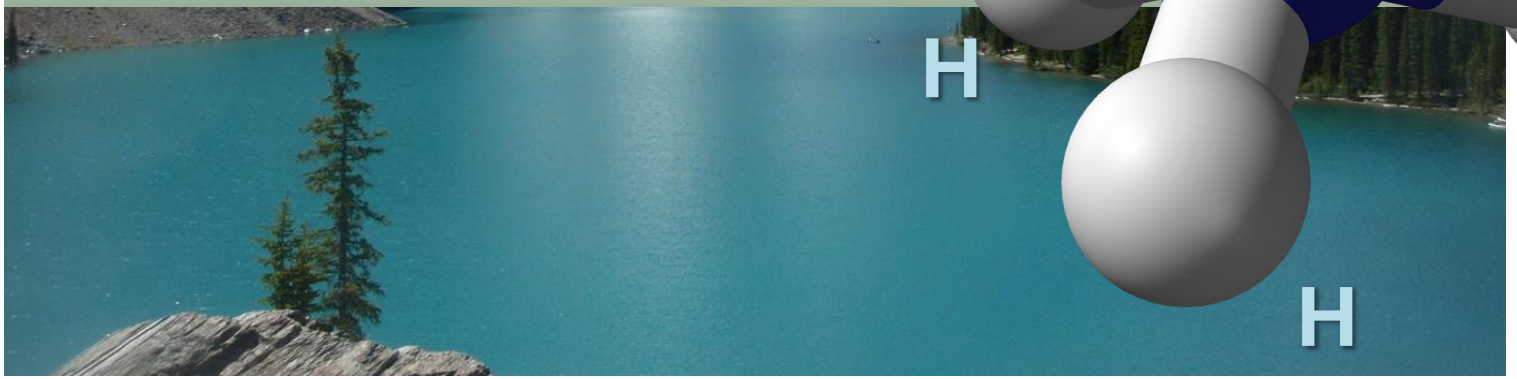
Making Sense

Ammonia – Natural Refrigerant

Natural Refrigerant, Environmentally Friendly:

- One of the most abundant gasses in the environment
- Exists all around us (air, water, soil, produced by our kidneys)
- Approx 1.7 times lighter than air
- Breaks down rapidly in the environment
- NH3 *(R-717): Nitrogen and Hydrogen*

- Ozone Depletion Potential (ODP) = 0
- Global Warming Potential (GWP) = 0



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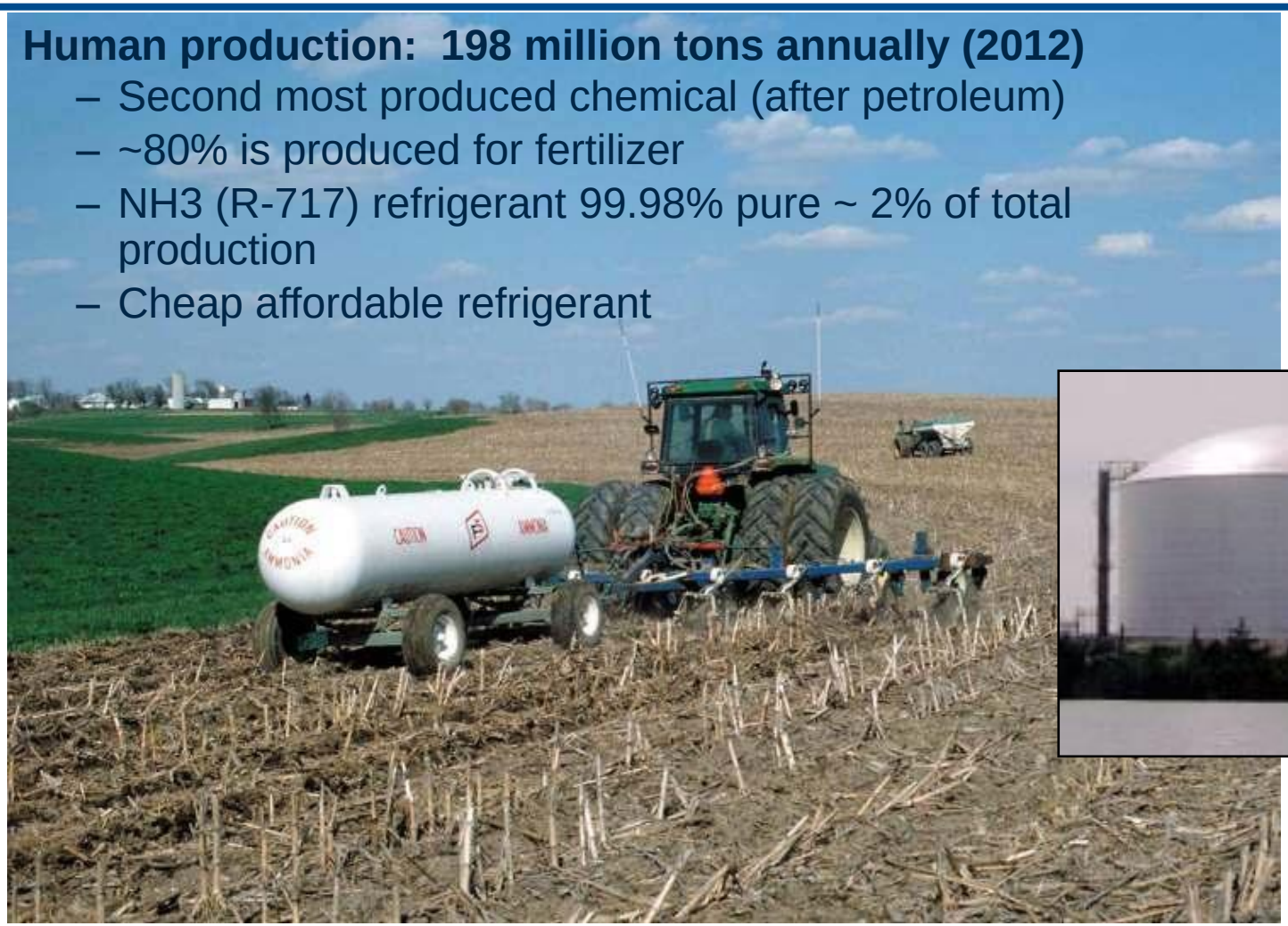
Ammonia Usage

Human production: 198 million tons annually (2012)

- Second most produced chemical (after petroleum)
- ~80% is produced for fertilizer
- NH3 (R-717) refrigerant 99.98% pure ~ 2% of total production
- Cheap affordable refrigerant



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Industrial Uses for Ammonia Refrigeration

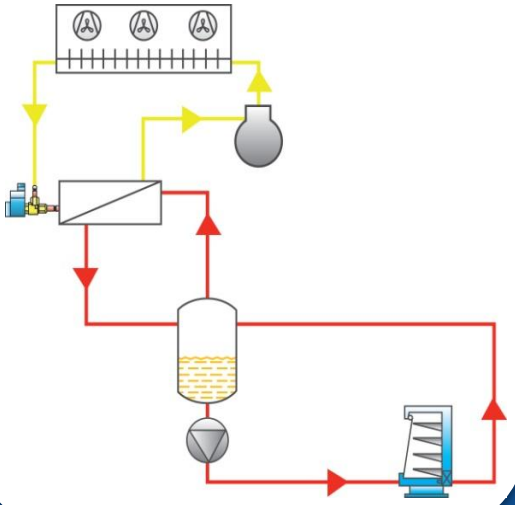
- **Less refrigerant required, smaller pipes required due to less mass flow:** ***over 9 times more energy content (Btu/lb) than HFC'***
  - *Ammonia +20F 478.5 BTU/lb*
  - *R404A +20F 51.1 BTU/lb*
- **Up to 25% more efficient in energy usage**
- **Excellent refrigerant for heat recovery**
- **Low cost refrigerant and oils:**
  - Mineral and semi-synthetic oils
- **Low maintenance, Low leakage rates require less refrigerant top up:**
  - Leaks found and dealt with immediately due to smell, alarms

Ammonia Applications

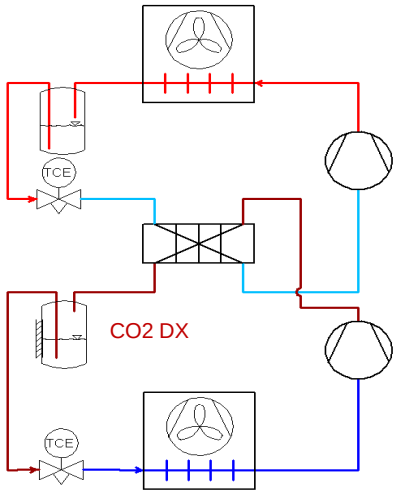
- **Food and beverage processing:**
  - Dairy, meat processing, breweries, baked goods, frozen foods
- **Refrigerated cold storage**
- **Recreational ice:**
  - Hockey rinks, curling, ice skating paths
  - Olympic speed skating, ski jump, bobsled tracks
- **Ground soil freezing, mining HVAC**
- ***HVAC, District heating and cooling, heat pumps***

CO_2 (R-744) for Refrigeration

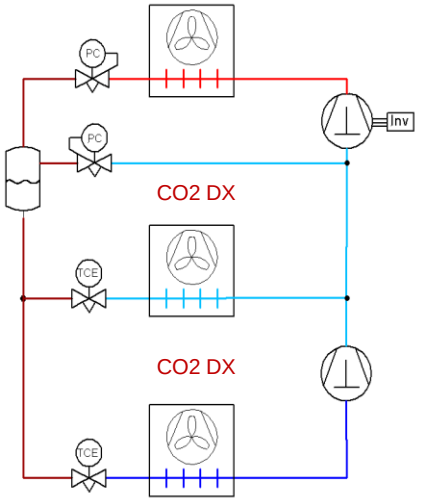
SECONDARY or Liquid Recirc.



CASCADE



TRANSCRITICAL BOOSTER



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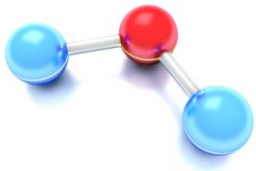
Properties of CO_2



- Natural refrigerant, OPD=0, GWP=1
- Non Toxic, Non Flammable, Odorless
- Atmosphere comprises approx. 0.04% CO_2 (370 ppm)
- Dangerous for people in concentrations exceeding 0.5% v/v (5000ppm)
- Heavier than air (will settle at the lowest level)
- Better heat transfer properties than HCFC and HFC
- Lower Viscosity in liquid and gas than HFCs

Properties of CO_2

- Typical smaller line sizes Vs DX piping systems
- Less sensitive to pressure drops
- Significant reduction in refrigerant charge Vs HFCs
- Inexpensive refrigerant compared with HCFC and HFC
- Excellent material compatibility
- System energy performance equivalent or better than traditional HFC systems depend on environment and system design
- High triple point -69.88F (-56.6C), Low critical point 87.8F (31C). (158F between them)

Basic Properties of R744 with R404A and R134a Refrigerants Commonly used in the Retail Sector.

Refrigerant	R744	R404A	R134a	R407A	R407F
Temperature at atmospheric pressure	**-109.3°F** (-78.5°C) Temp of dry ice	-50.8°F (-46°C) (Saturation temp.)	-14.8°F (-26°C) (Saturation temp.)	-41.8°F (-41°C) (Mid Point Saturation temp.)	-45.5°F (-43°C) (Mid Point Saturation temp.)
Critical temperature	**87.8°F** (31°C)	161.6°F (72°C)	213.8°F (101°C)	179.6°F (82°C)	181.4°F (83°C)
Critical pressure	**1056psig** (72.8 bar g)	503psig (34.7 bar g)	590psig (40.7 bar g)	641psig (44.2 bar g)	674psig (46.5 bar g)
Triple point pressure	**75 psia** (4.15 bar abs)	0.44psia (0.03 bar abs)	0.734psia (0.005 bar abs)	0.18psia (0.013 bar abs)	TBC
Pressure at a saturated temperature of 20°C	**815psig** (56.2 bar g)	144psig (9.9 bar g)	68psig (4.7 bar g)	133psig (9.2 bar g)	139psig (9.6 bar g)
Global warming potential	1	3922	1430	1990	1824

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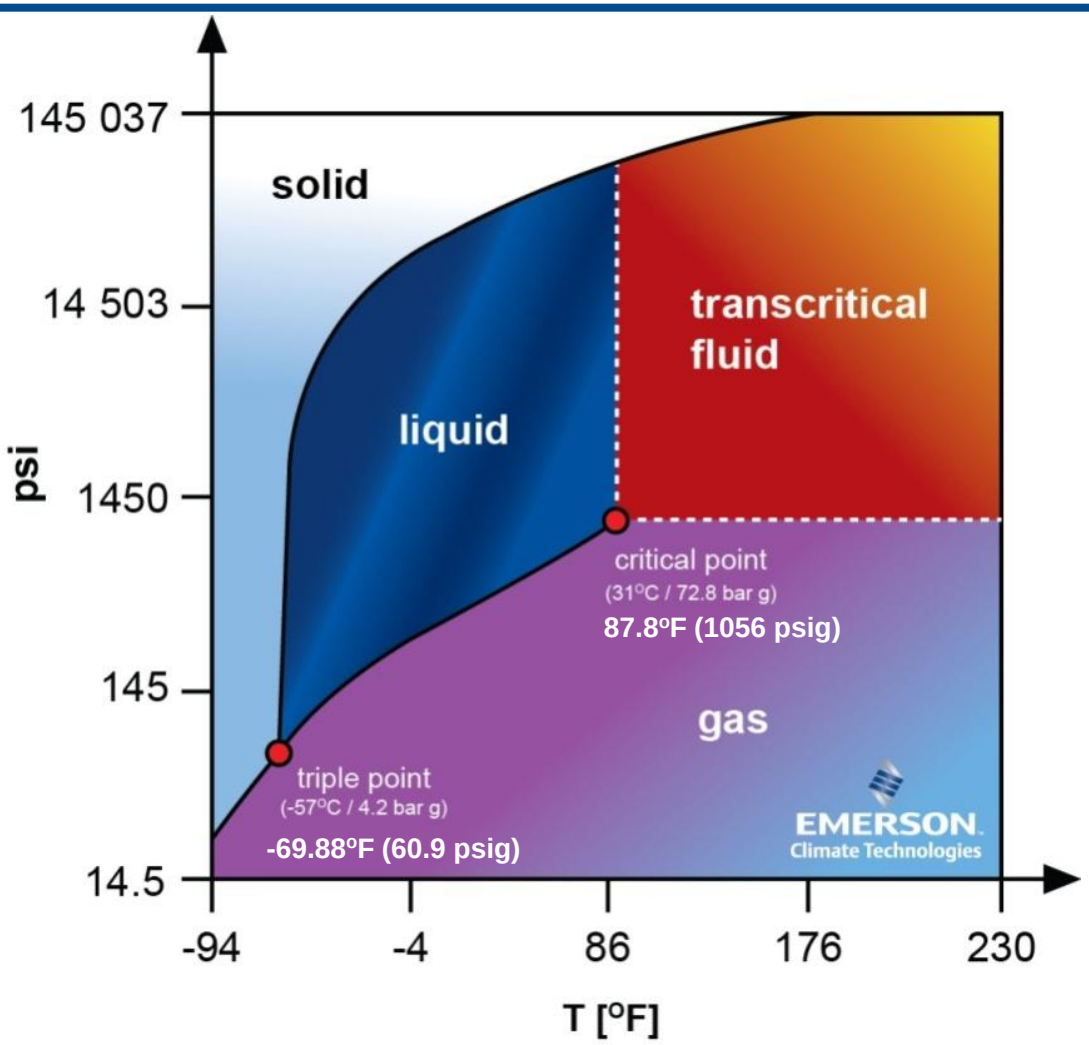
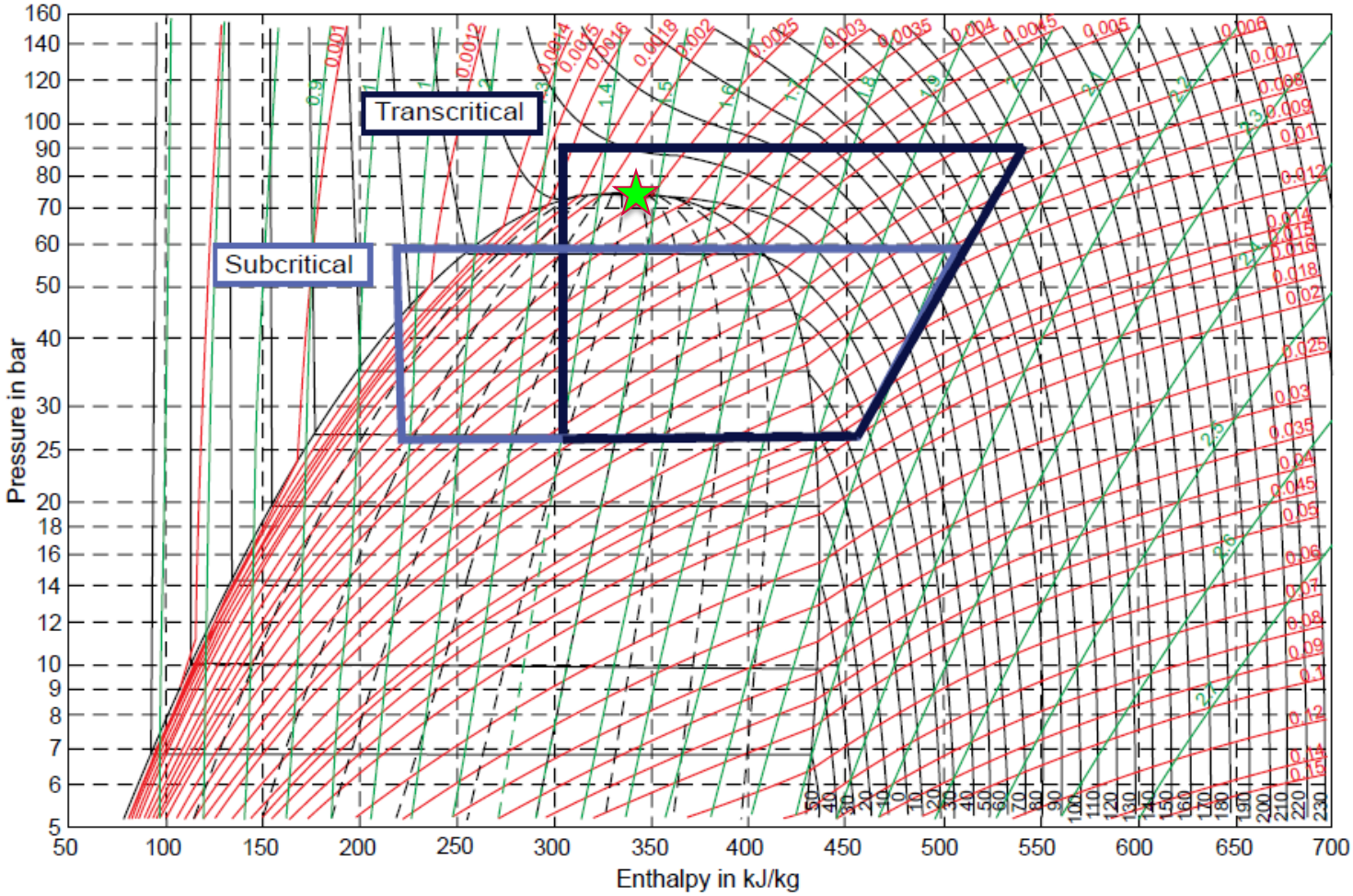
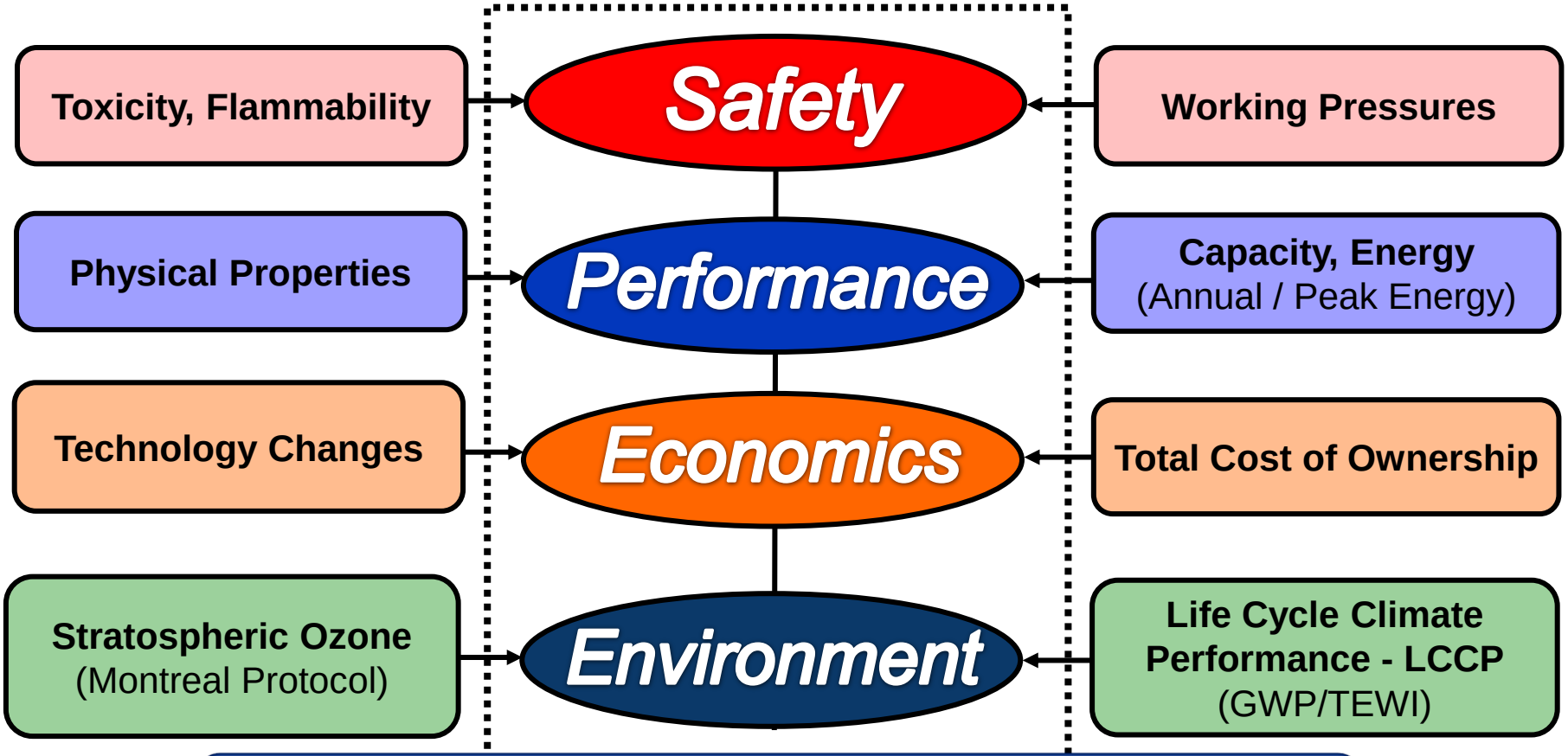
Pressure-Temperature Chart For CO_2



Subcritical vs. Transcritical Operation



Holistic Approach To Evaluating Choices Can Minimize "Unintended Consequences"



System focused approach to evaluating refrigerants using a standard method of comparison is important

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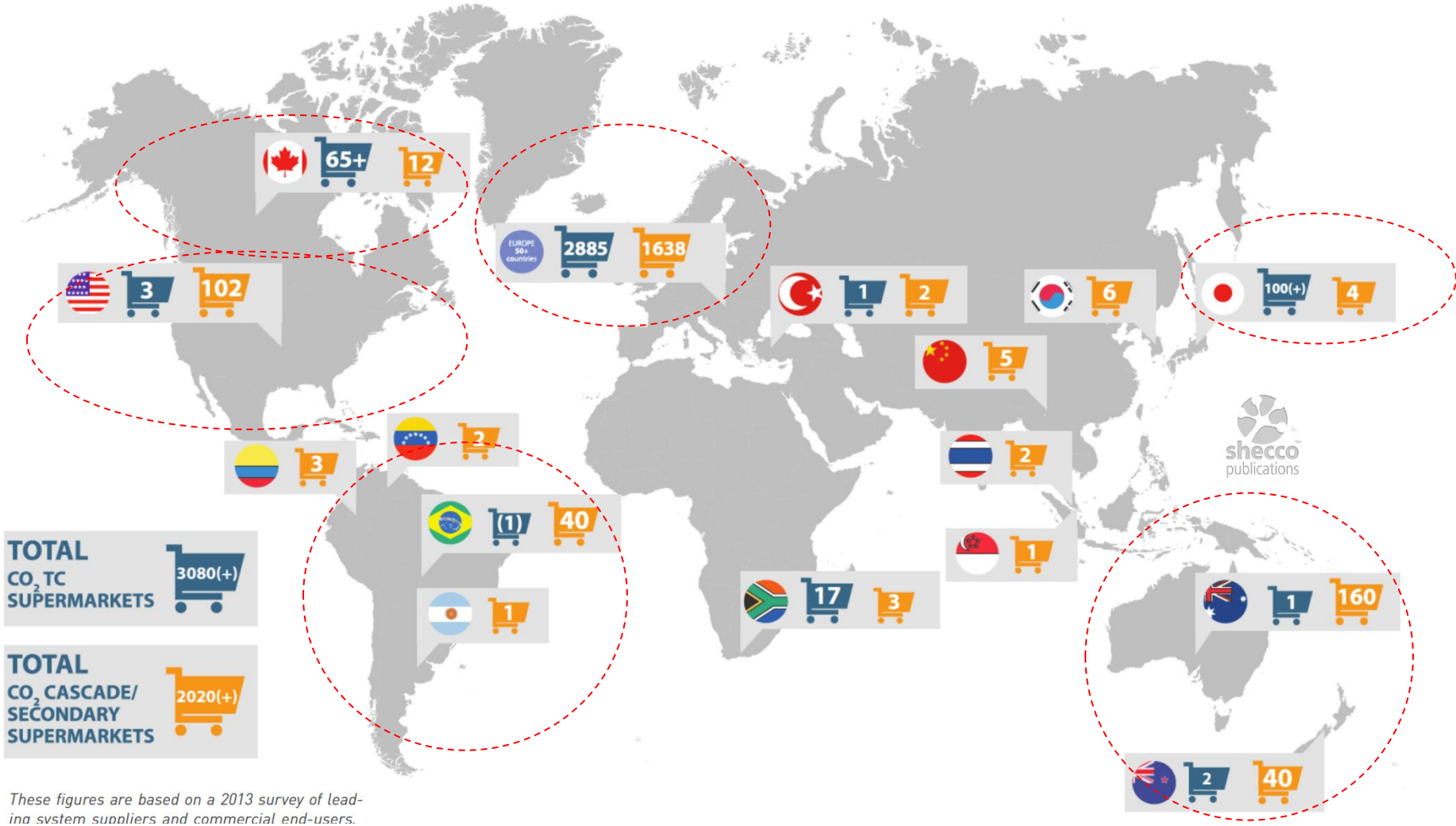
Global CO_2 Presence in Refrigeration

MAP OF CO_2 TRANSCRITICAL & CO_2 CASCADE/SECONDARY STORES WORLDWIDE IN 2013

DATA BY COUNTRY

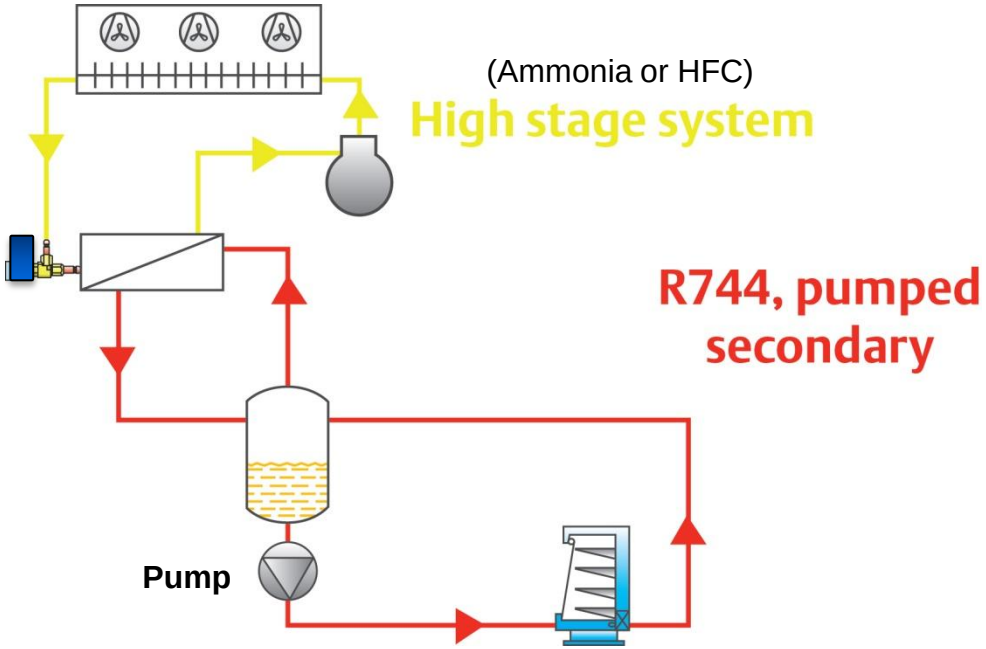


TOTAL CO_2 TC SUPERMARKETS 3080(+)

TOTAL CO_2 CASCADE/ SECONDARY SUPERMARKETS 2020(+)

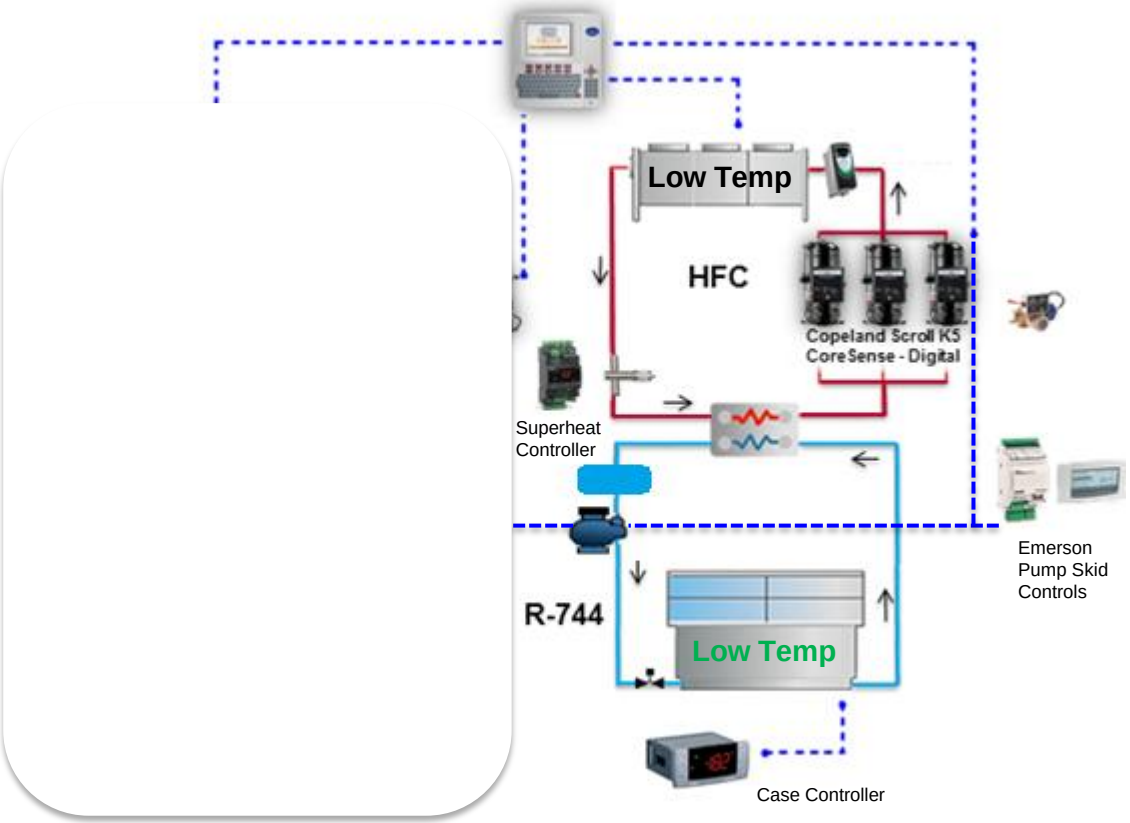
These figures are based on a 2013 survey of leading system suppliers and commercial end-users.

CO_2 Secondary System

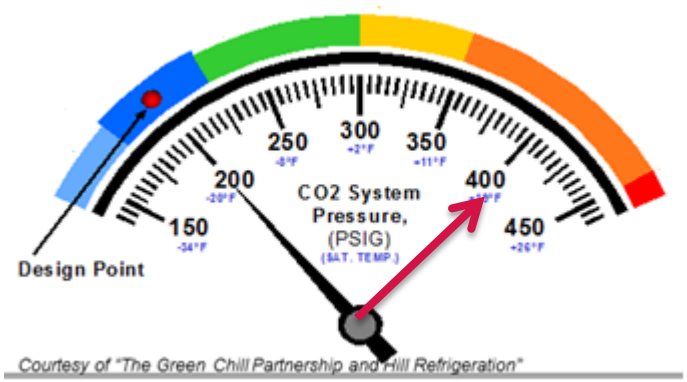


- The high stage system cools the liquid CO_2 in the secondary circuit.
- The CO_2 is pumped around the load.
- **It is volatile, so unlike a conventional secondary fluid such as glycol it does not remain as a liquid,** instead it partially evaporates.
- It therefore has a significantly greater cooling capacity than other secondary fluids.
- This reduces the pump power and the temperature difference at the heat exchanger.

CO_2 Secondary System - Schematic



The CO_2 would typically be cooled to
-20^{O}F (200 psig) for the LT load
+20^{O} F (407 psig) for the MT load
The high stage system is a simple chiller type system, typically running on an HFC or HC or Ammonia.



Making Sense

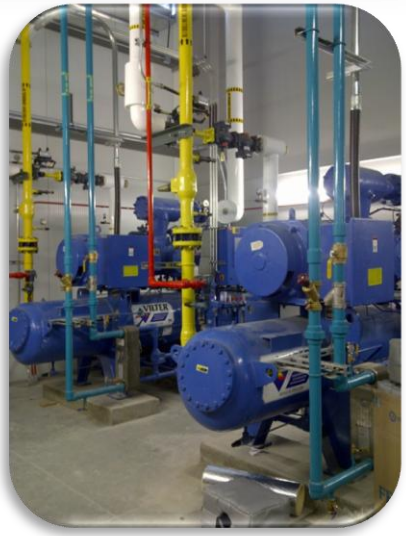
Cold Storage Warehouse Improves Efficiency with Ammonia / Pumped CO_2 System

Results

- Ammonia / CO2 Brine System
- 1000 tons of efficient ammonia / CO2 refrigeration
- Dual slide valve efficiency avoids $100,000 of VFDs
- 15% higher efficiency than comparable technologies
- Non-ozone depleting refrigerants with Zero global warming potential
- Vilter Single screw with ammonia achieves increased performance
- Designed for 20 years service without costly maintenance

Application

Pumped liquid CO2 secondary system refrigerated by ammonia for 240,000 square foot product and dairy cold storage warehouse



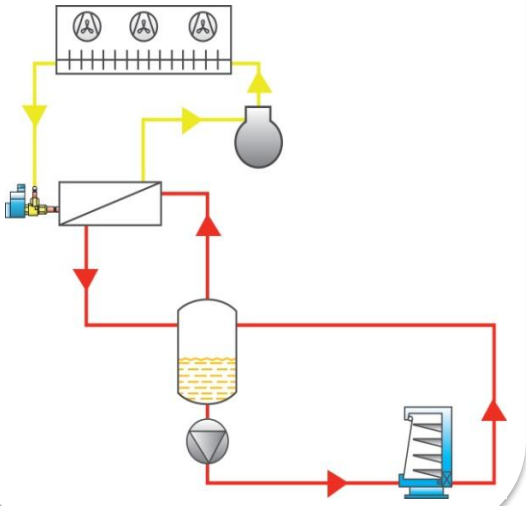
Customer

With annual sales of over $100 billion and over 65,000 employees, METRO INC. A leader in the food and pharmaceutical sectors in Quebec and Ontario where it operates a network of more than 600 food stores as well as over 250 drugstores.

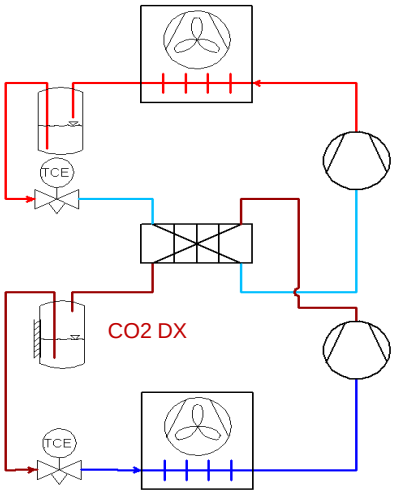
CIMCO is an international refrigeration leader in the industrial refrigeration food, beverage and cold storage markets.

Selecting the Best System
Booster vs. Cascade vs. Secondary

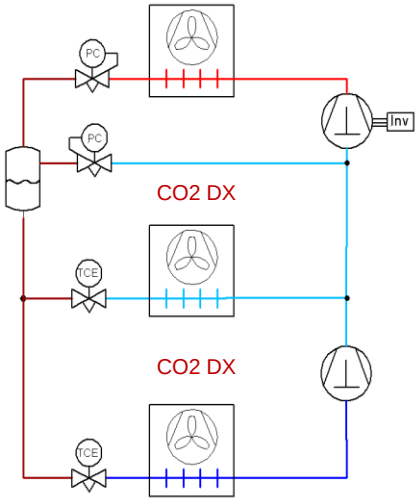
SECONDARY



CASCADE



TRANSCRITICAL BOOSTER



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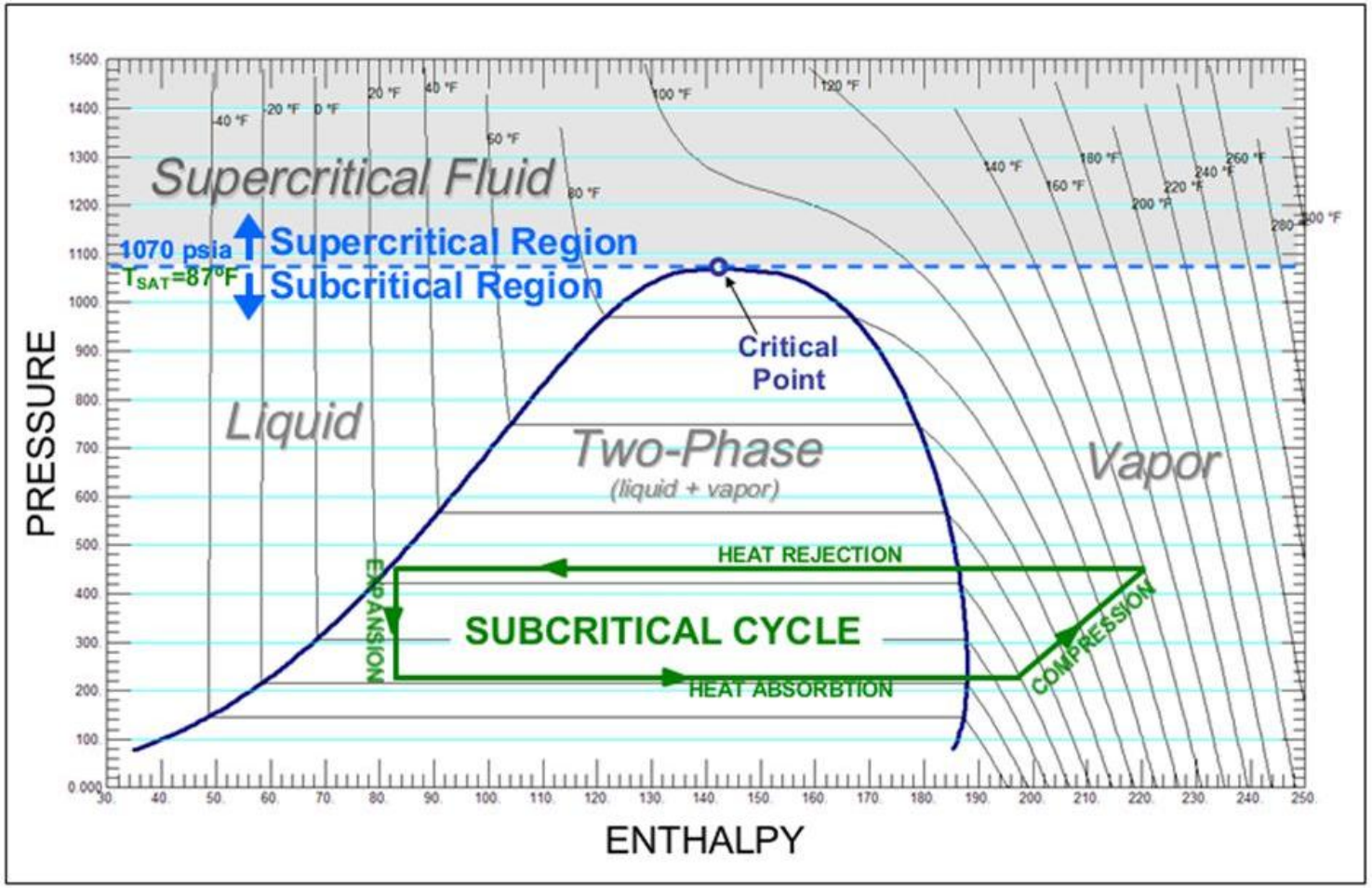
CO_2 Subcritical Refrigeration Cycle

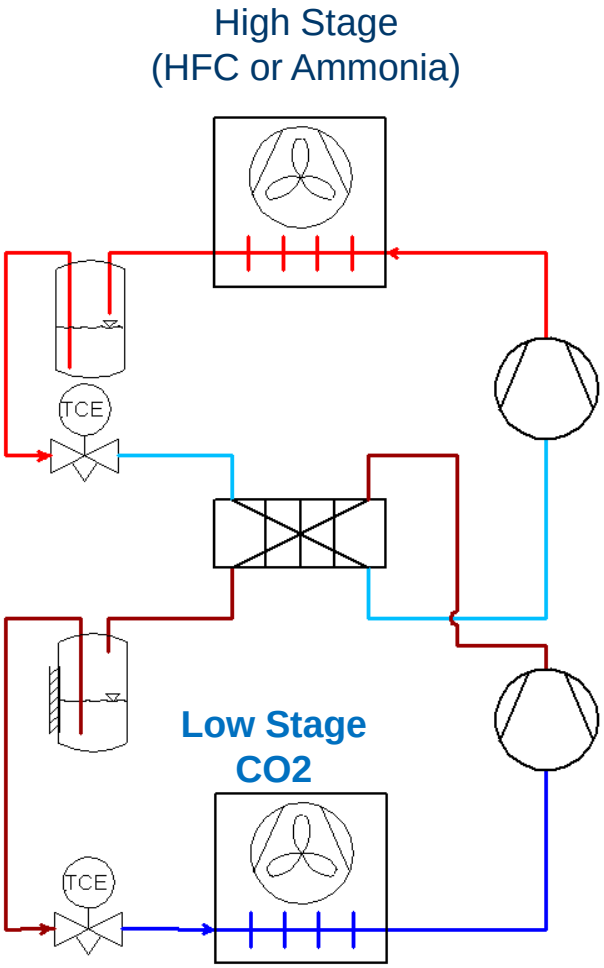


Making Sense

Introduction to Cascade - Simple Systems

Simple Cascade System comprises:

- The low stage provides the cooling load
  - ✓ It uses CO_2, and is always subcritical
- The high stage, absorbs heat from the condensing CO_2 at the cascade heat exchanger.
- The CO_2 condensing temperature is maintained below the critical point.
- The high stage is usually a simple, close coupled system.
- It is controlled by the pressure in the low stage receiver.
- Pressure similar to R410A



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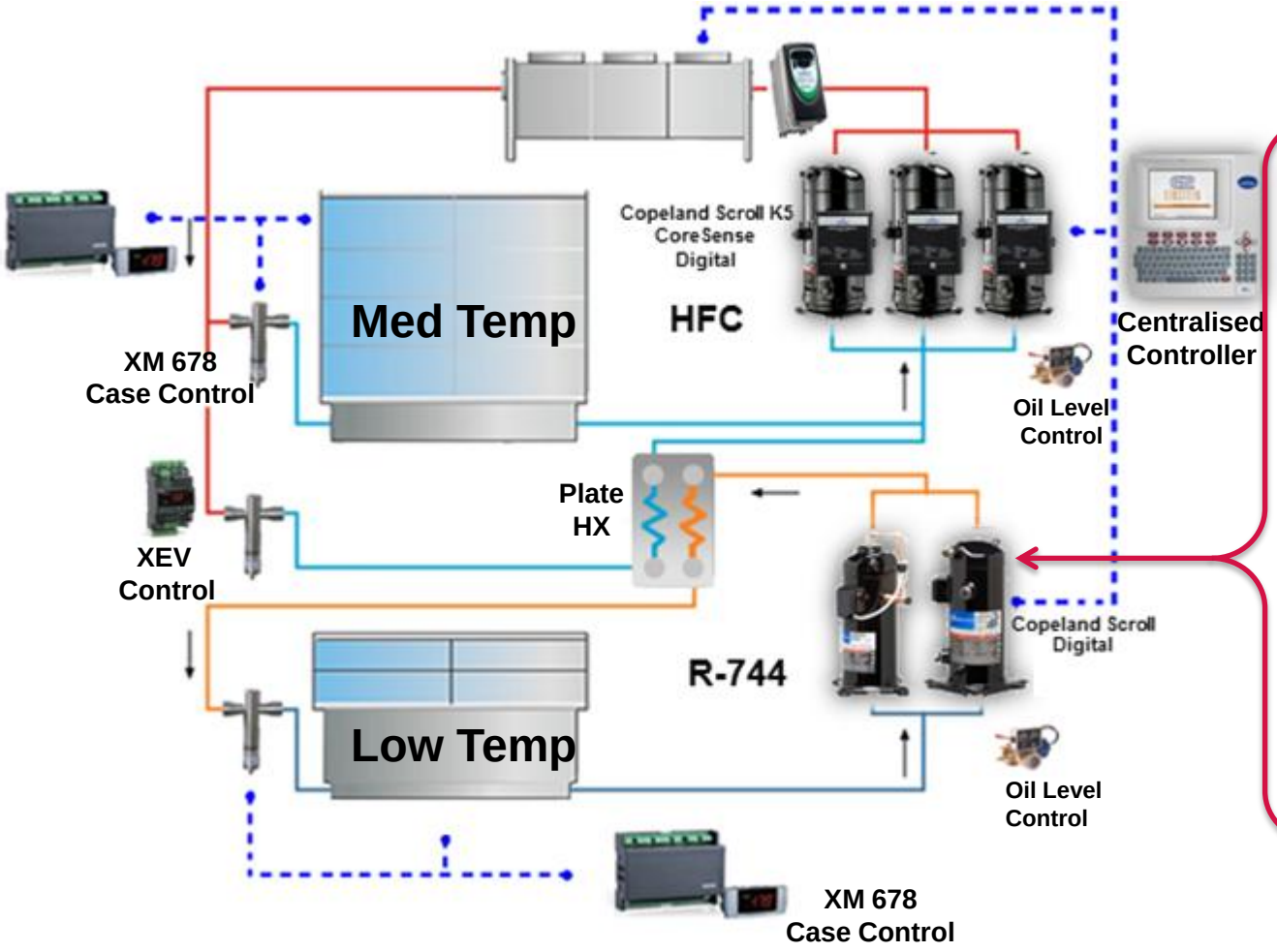
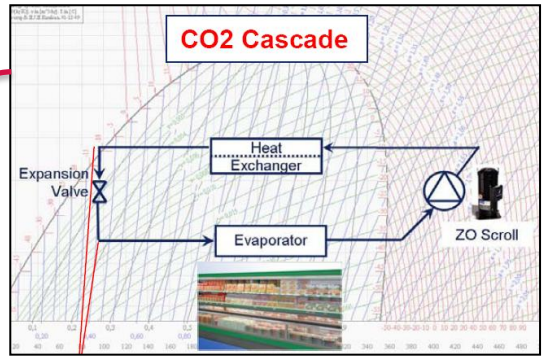
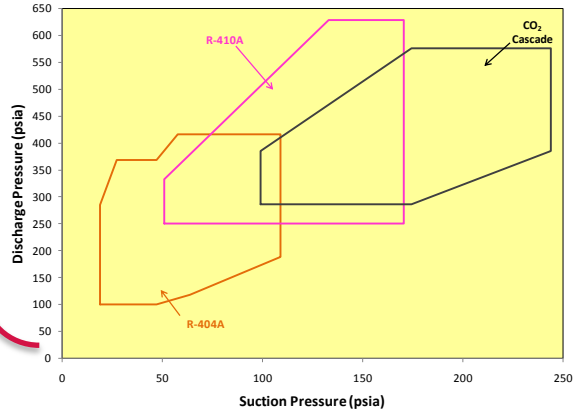
Typical Retail Cascade System - Schematic







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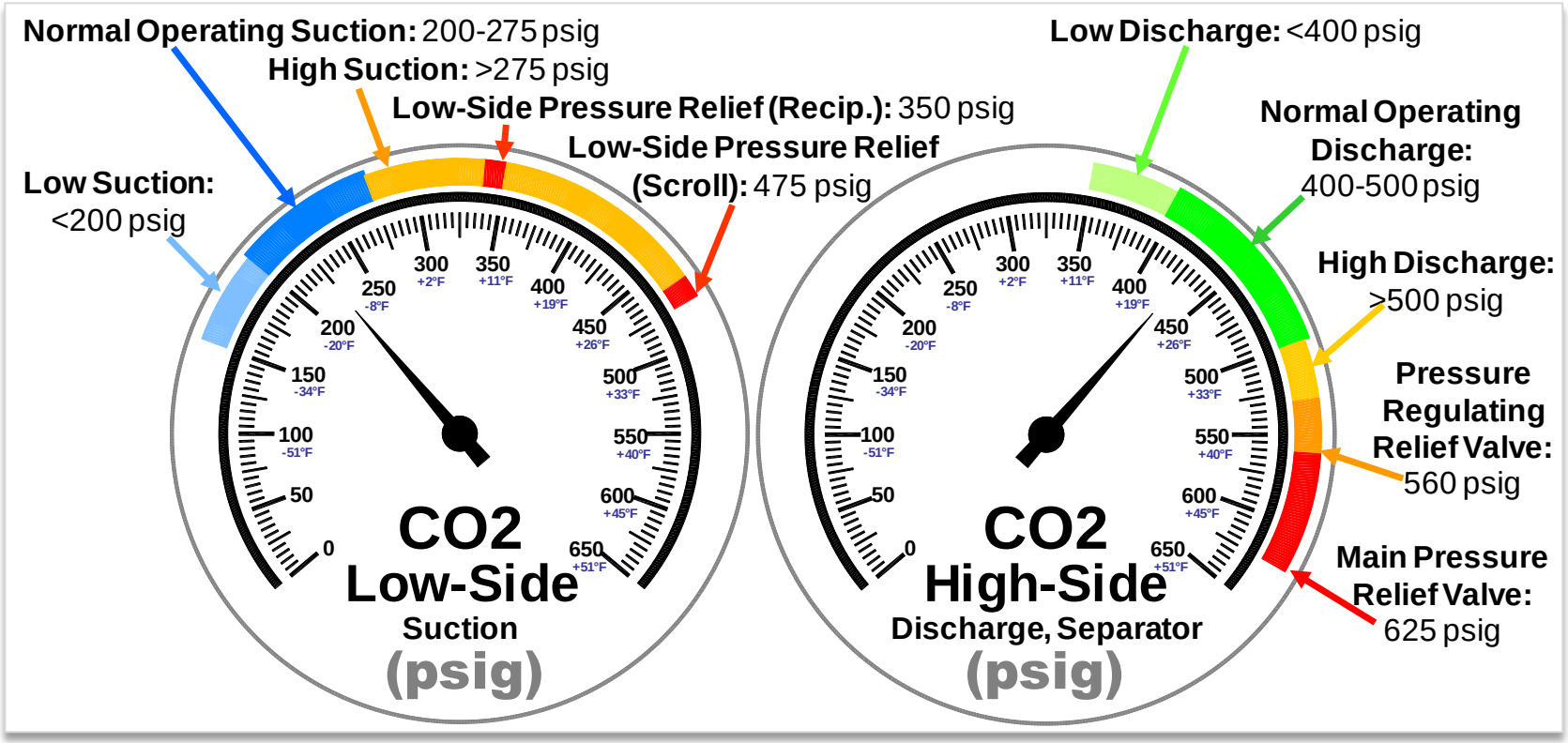
System Typical Operating Pressures Cascade



Low-Side (Suction)

- **Typ. Operating Suction 200-275 psig**

High-Side (Discharge and Receiver)

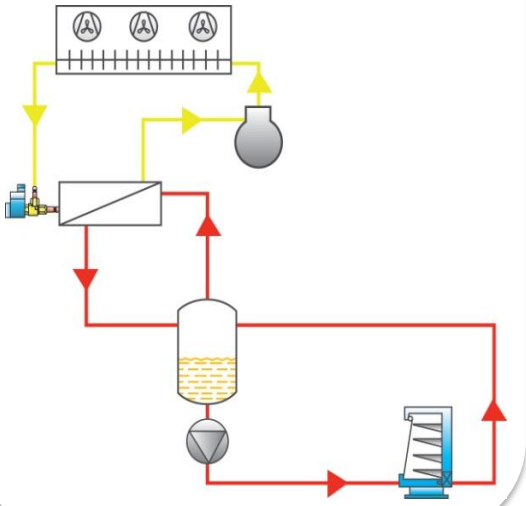
- **Typ. Operating Discharge 400-500 psig**

Courtesy of "The Green Chill Partnership and Hill Refrigeration"

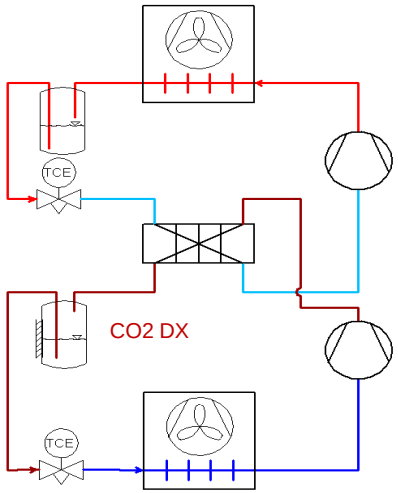
Making Sense

Selecting the Best System
Booster vs. Cascade vs. Secondary

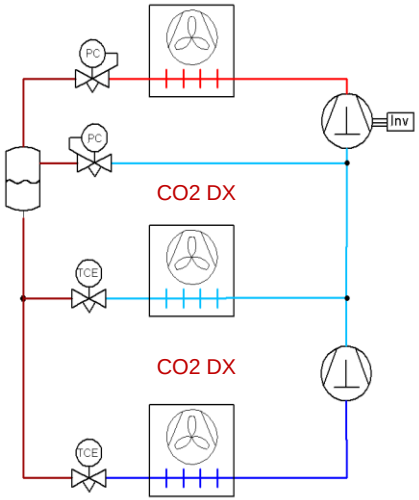
SECONDARY



CASCADE



TRANSCRITICAL BOOSTER



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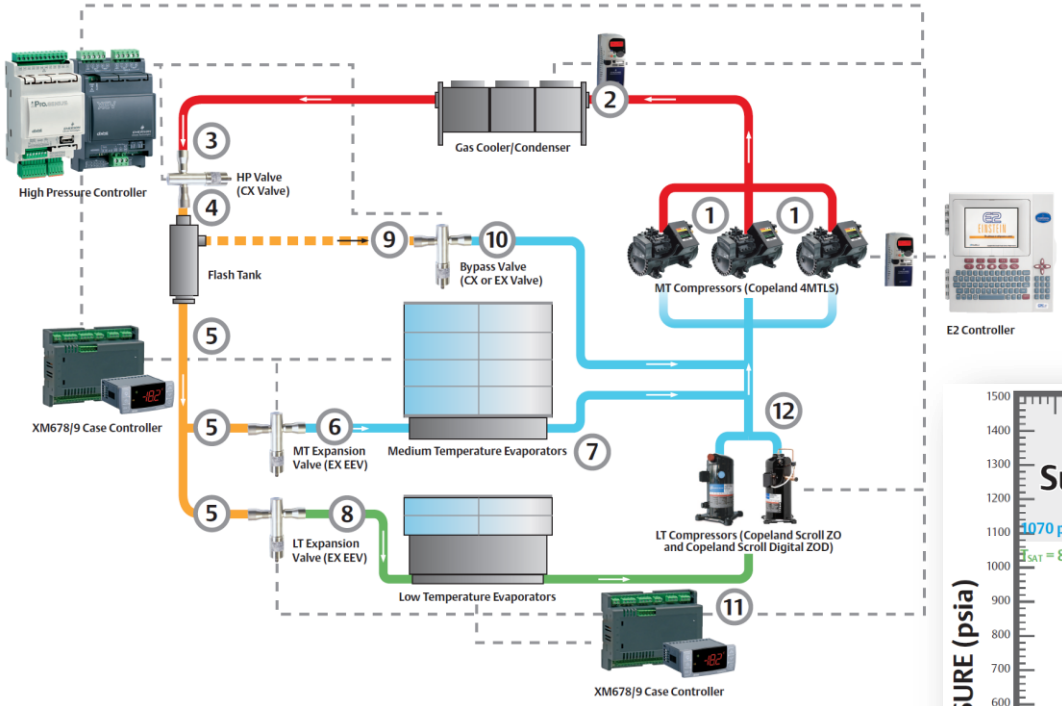
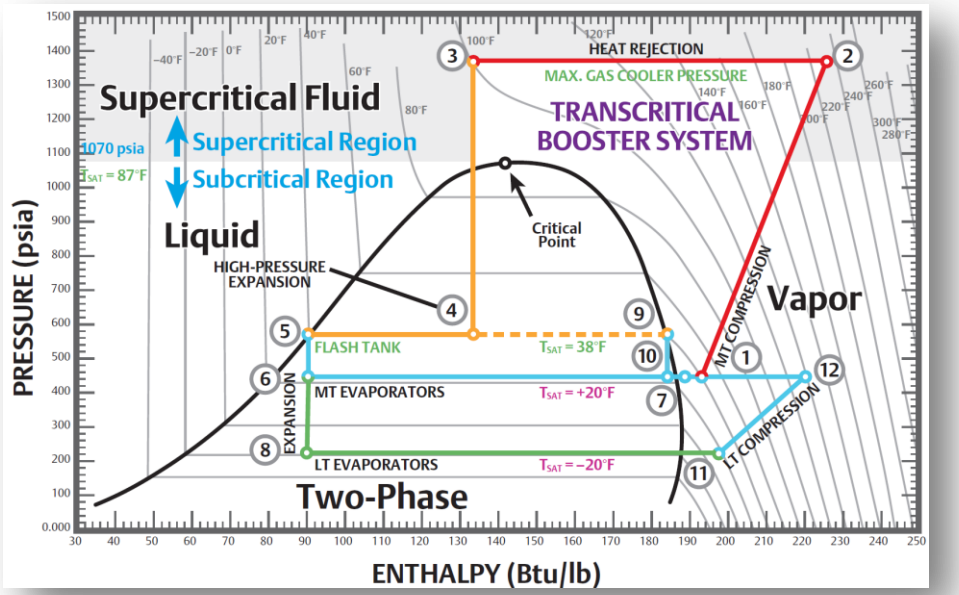
CO_2 Booster Refrigeration System
Transcritical Compressors



- PRV Relief Valves 66 /135bar (957 / 1958psig)
- High Side Pressure 800 to 1740 psig
- Liquid Line Pressure 550 to 650 psig
- Medium Temp Suction Pressure 350 to 500 psig
- Low Temp Suction Pressures 175 to 250 psig



Making Sense

Gas Cooler Design

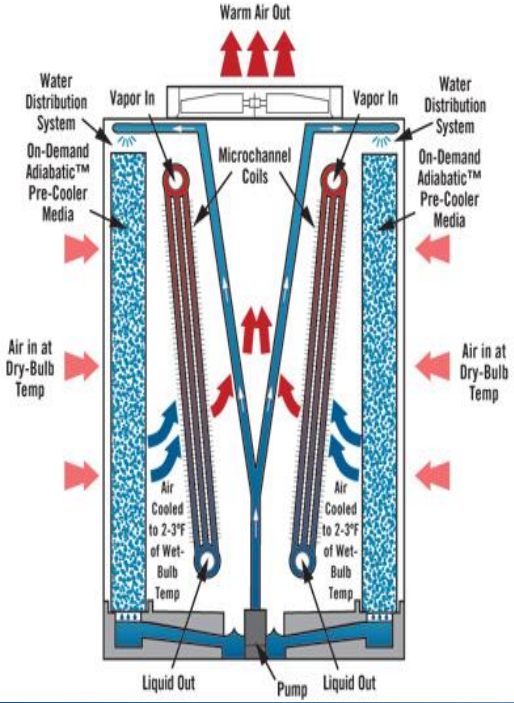
Alternatives for improving the system efficiency:

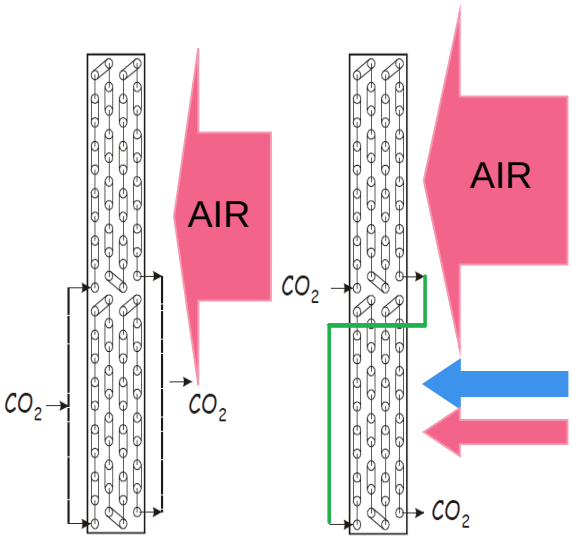
1. Evaporative Condenser: keeps system subcritical up to wet bulb temperature of 75F
2. Gas cooler with evaporative subcooling

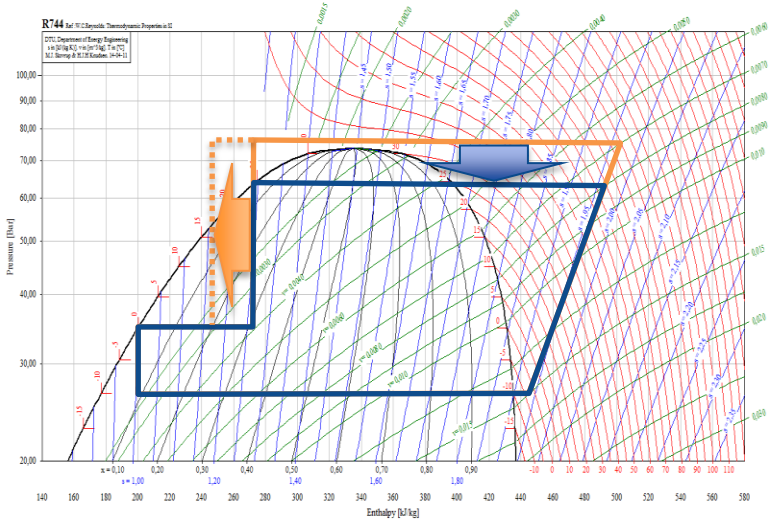
ADIABATIC

DRY

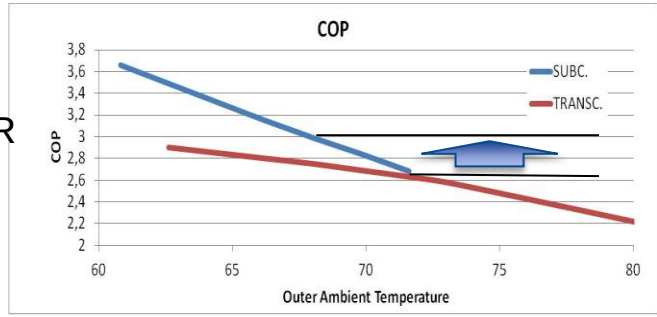
MIXED





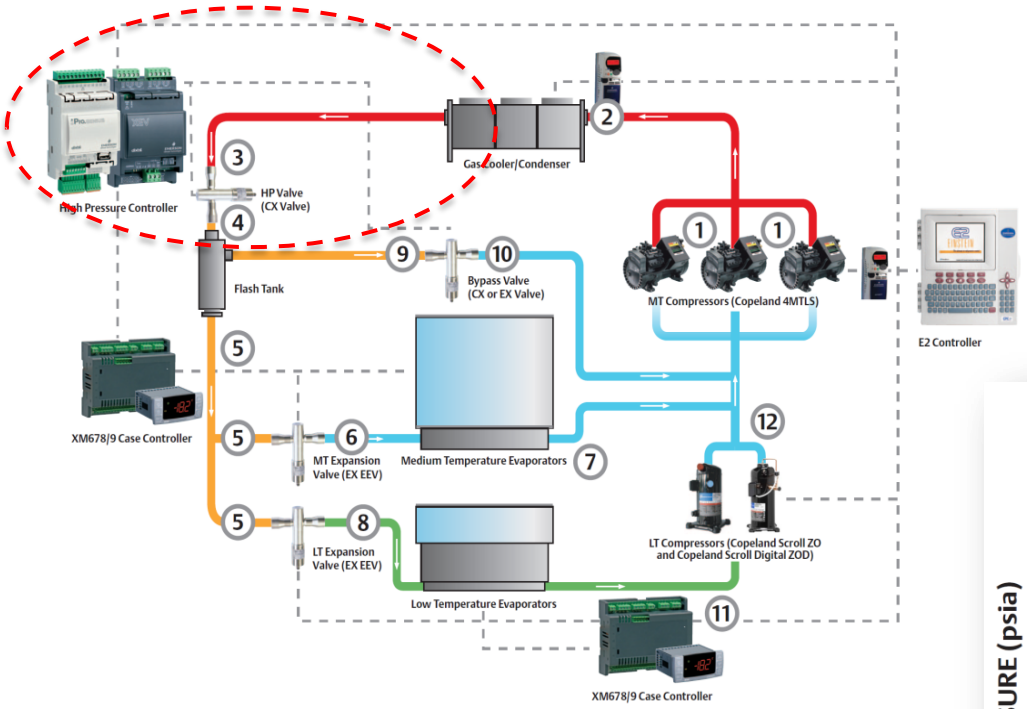


WATER & AIR

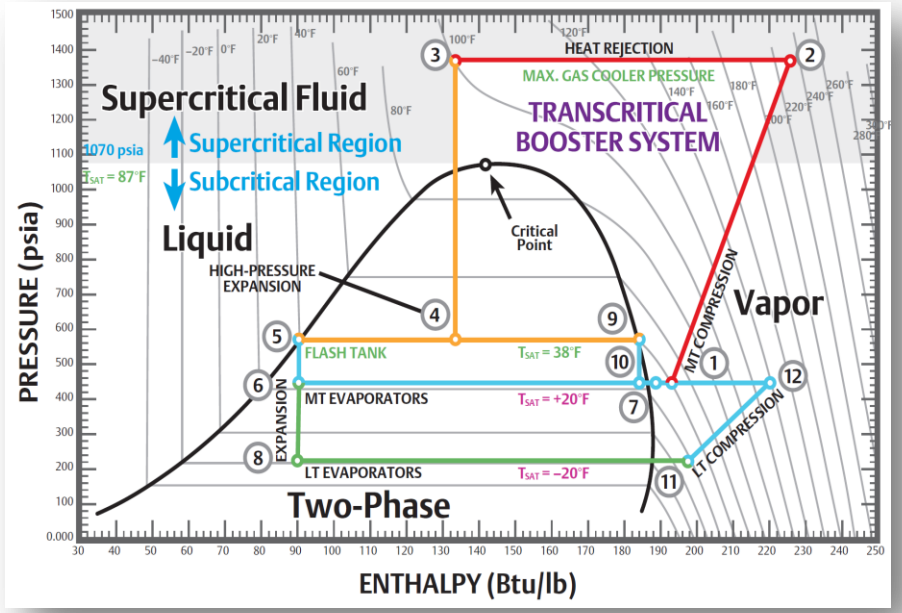


CO_2 Booster Refrigeration System

High Pressure Controller Valve Combination

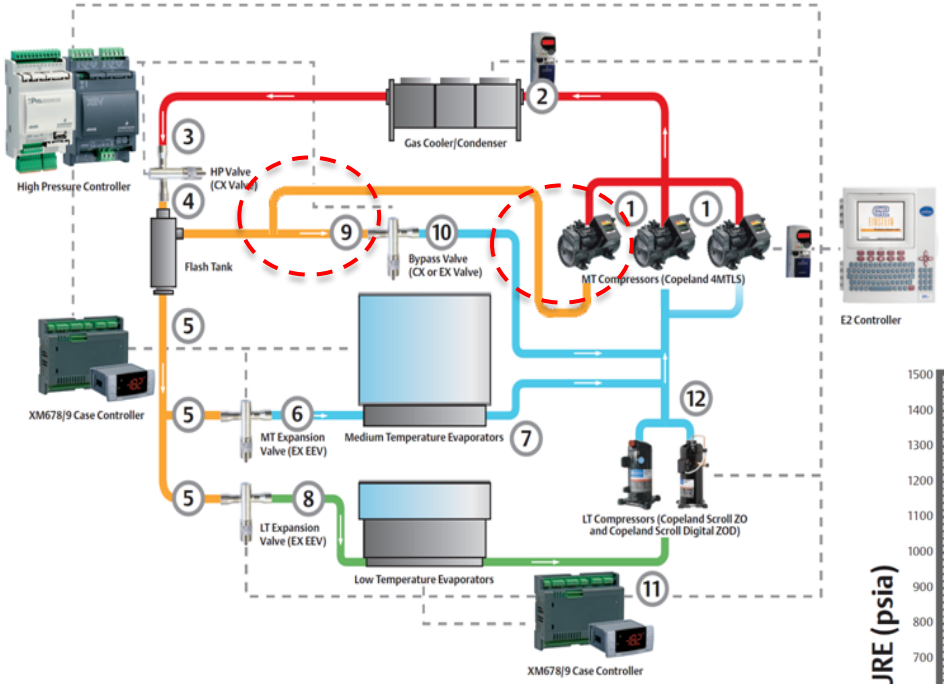


- Helps maintain sub cooling in condenser when in subcritical mode
- Create pressure drop into the flash tank
- Optimizes COP during transcritical operation.
- Emerson High Pressure Controller &"CX" Valve

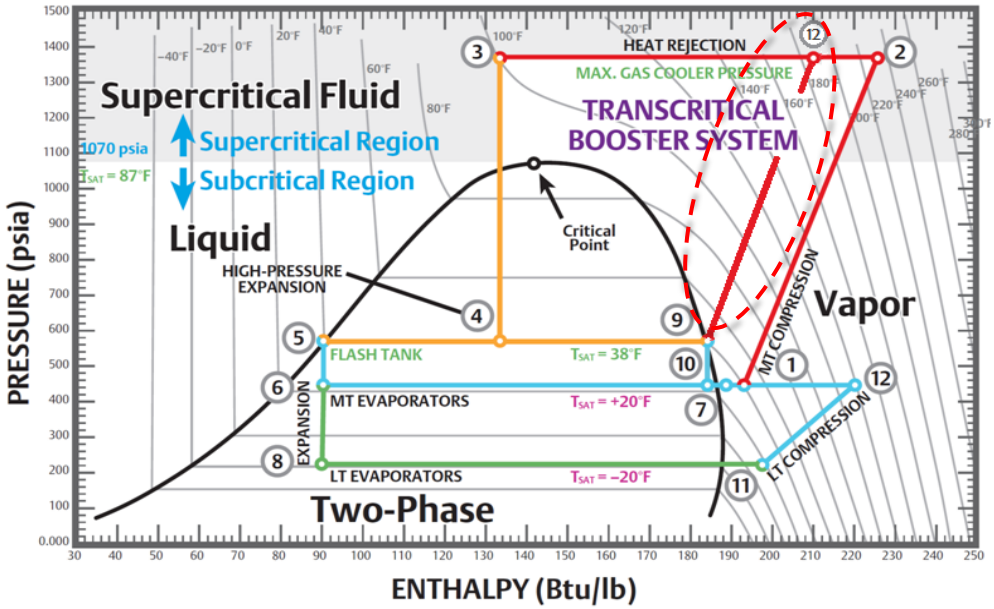


Making Sense

CO_2 Booster Refrigeration System
With Parallel Compression

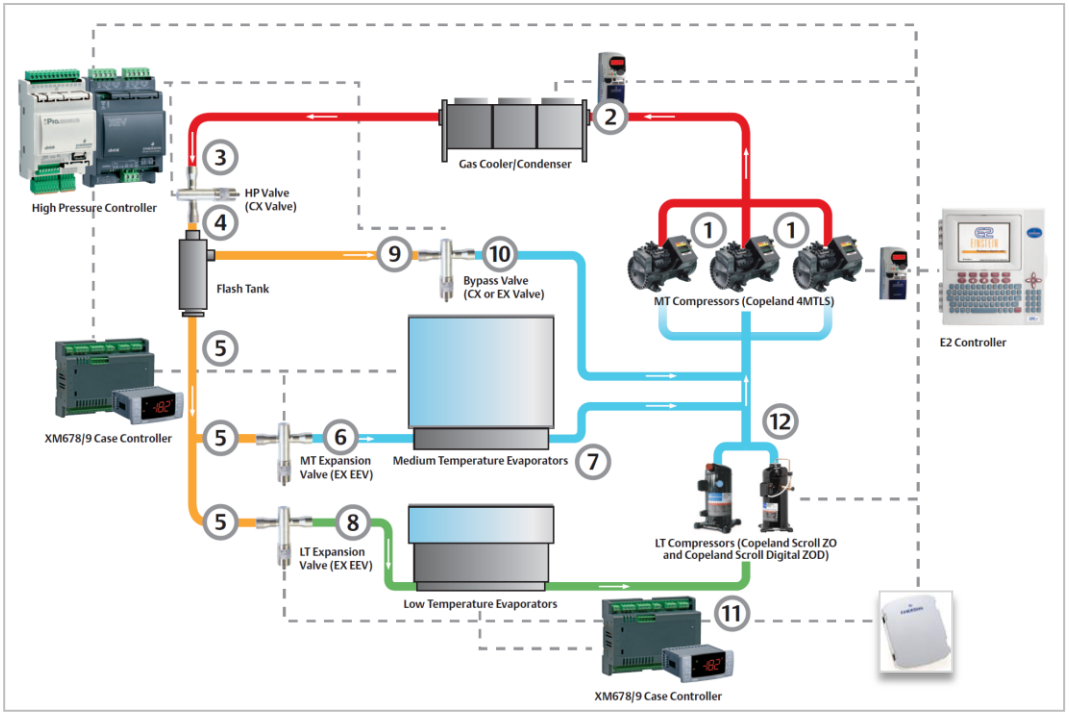


- Flash gas is compressed by a different compressor
- Higher gas density of CO_2, results in smaller compressor displacement
- 8% higher efficiency
- Smaller Gas Cooler
- By-pass valve remains to manage low load and low condensing conditions



Making Sense

CO_2 Booster Refrigeration System
Complete Emerson Offering



Connectivity with

- Transcritical Compressors
- CoreSense Protection
- Compressor HSK VFD
- Condenser Fan HSK VFD
- High Pressure Controller & Valve
- Bypass Valve
- Case Controllers and EEV
- System Protectors
- MRLDS CO2 Leak Detectors
- Sub critical Scrolls
- Digital Enhanced Suction Control
- Ultra site floor plans via Surface Pro tablet
- Pro-Act Remote monitoring, enterprise services

Making Sense

Summary

• Global Regulations are causing end users to seriously look at their refrigerant options that best suits their company targets

• Although Hydrocarbons and Ammonia have application challenges Vs HFC their uses continue to increase in specialized application.

•Cascade (sub critical CO_2) and secondary systems (liquid Recir) are usually used in high ambient areas such as southern Europe, the mid to southern USA and much of central and south America, Asia, Africa and Australia.

•Transcritical systems are usually used in areas where the ambient temperature is generally low (i.e. predominantly below 77F), such as northern Europe and Canada, and Northern US. New product development and system designs are allowing improved efficiency in warmer climates.

•Emerson is ready and fully committed to supporting Natural refrigerants.

Thank You!

Questions?

Making Sense