Natural Refrigerant Training Summit

Building a Sustainable Workforce

CO_2 : Why, How, and What Next

John Bento

Hussmann

NORTH AMERICAN Sustainable Refrigeration Council

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Natural Refrigerant Training Summit

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Who We Are

A 501c3 nonprofit working to create a sustainable future for supermarket refrigeration by removing barriers to natural refrigerant adoption.

160+
member companies

55K+
food retail locations

Goals

- Build a sustainable technician workforce
- Increase funding for natural refrigerant equipment
- Improve technology options, education, and awareness

What are Natural Refrigerants?

CO_2	C_3H_8	NH_3
R744	**R290**	**R717**
Carbon Dioxide	Propane	Ammonia

NORTH AMERICAN
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CO_2

Why, How, and What Next?

John Bento

HUSSMANN®

3/8/2024

About Me

- 25+ years in Education
- 15 years teaching adult learners
- 5 years HVACR experience (US Navy)

PEACE CORPS

UNITED STATES NAVY

Learning Objectives

1. How did we get (back) to CO_2??
2. CO_2 Properties and why it is different
3. Cascade Systems Overview
4. Transcritical System Overview
5. Overall Future of Natural Refrigerants

Let’s take a trip back in time…

Refrigerant Types

Natural

but with a bit of work…

- 1800's, peaking in the 1880's
- Americans used over 5 million TONS of ice annually
- Why my grandma O'Brien referred to the fridge as an "Ice Box"

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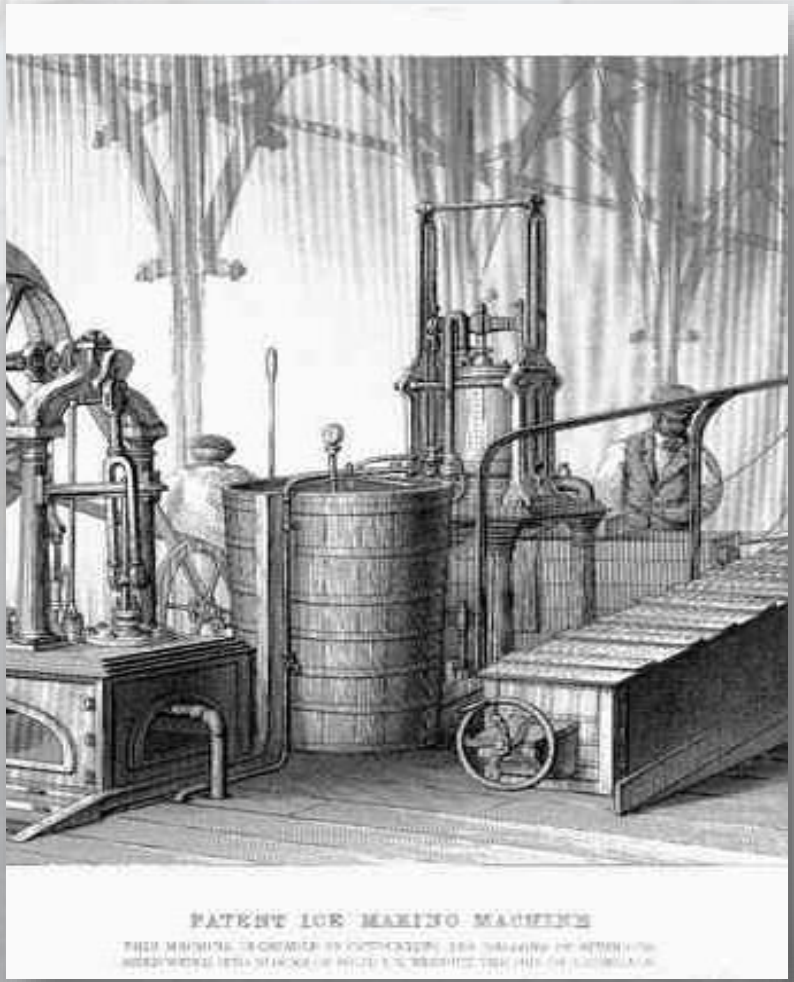
Early Days
(LATE 1800's - 1929)



- Ammonia (NH_3)
- Methyl Chloride (CH_3Cl)
- Sulfur Dioxide (SO_2)
- Carbon Dioxide (CO_2)

- "Whatever Worked" era
- Availability and ability to work with the equipment of the time.
- Some are still used today (Ammonia, Propane, CO_2)
- Others fell out of favor due to high toxicity

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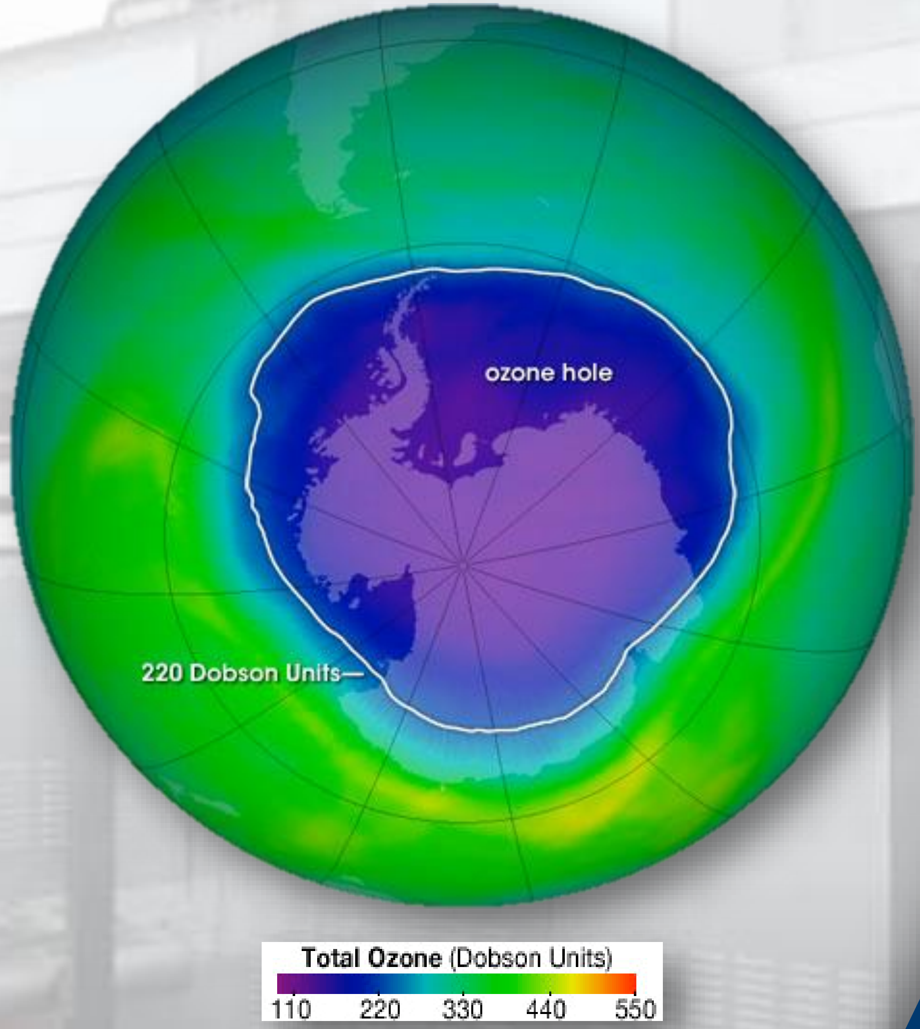
Age of Synthetics

(1930's – 1990's)

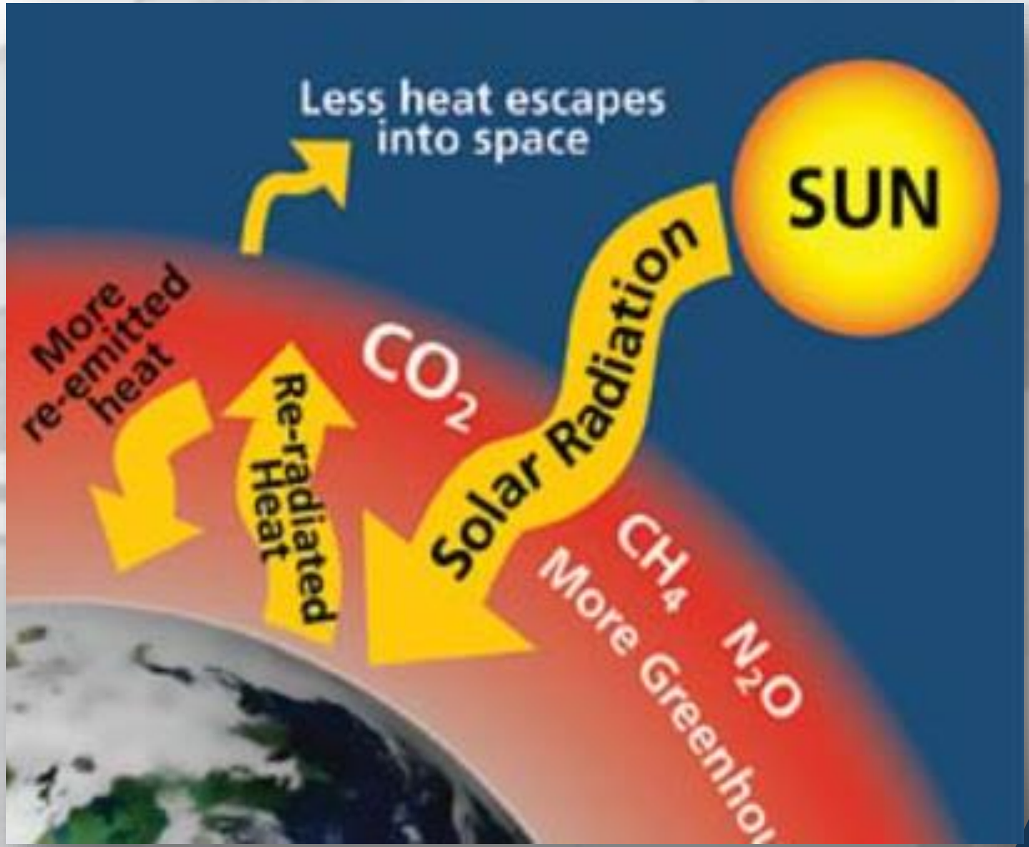
- Invented by GM (who owned Frigidaire)
- Wanted a "safe and stable" (non-toxic and non-flammable) refrigerant
- Used CFC (Chlorofluorocarbons) & HCFC's (Hydrochlorofluorocarbons)
- R-12, R-11, R-22, and R-21
- Ammonia still held over for large industrial applications

Age of Synthetics
(1930’s – 1990’s)



- However, CFC’s and HCFC’s depleted the Ozone layer which protects us from harmful radiation
- Due to their stability, synthetics don’t break down
- If unchecked, UV radiation would affect skin cancer, agriculture, and widespread environmental dangers
- The Montreal Protocol began the phase out of CFC’s

Age of Synthetics
(1930's – 1990's)



- While most refrigerants now have very little effect on the ozone layer, we now have global warming to deal with…..
- All chemicals will trap outgoing radiation at different rates. This is known as Global Warming **Potential** (GWP)
- ***Note the word "Potential".*** Refrigerants are not a danger unless they get into the atmosphere

Many Synthetics are being Regulated

- GWP (Global Warming Potential) is a value used to gauge impact in the atmosphere
  - R-12 = 10,600
  - R-22 = 1,700
  - R-448A = 1,170
  - R-513A = 630
  - R- 744 = 1 → CO_2

two tanks R-22 = one tank R-404A = annual fuel for 14 cars

December 2020—Congress passes the ‘AIM’ Act

- Empowers the EPA to reduce production and consumption of HFC’s by 85% by 2036
- Places GWP limits on systems

	GWP	
Retail food refrigeration – stand-alone units	150	January 1, 2025
Retail food refrigeration – refrigerated food processing and dispensing equipment	150	January 1, 2025
Retail food refrigeration – supermarket systems with refrigerant charge capacities of 200 pounds or greater	150	January 1, 2025
Retail food refrigeration – supermarket systems with refrigerant charge capacities less than 200 pounds charge	300	January 1, 2025
Retail food refrigeration – supermarket systems, high temperature side of cascade system	300	January 1, 2025
Retail food refrigeration – remote condensing units with refrigerant charge capacities of 200 pounds or greater	150	January 1, 2025
Retail food refrigeration – remote condensing units with refrigerant charge capacities less than 200 pounds	300	January 1, 2025
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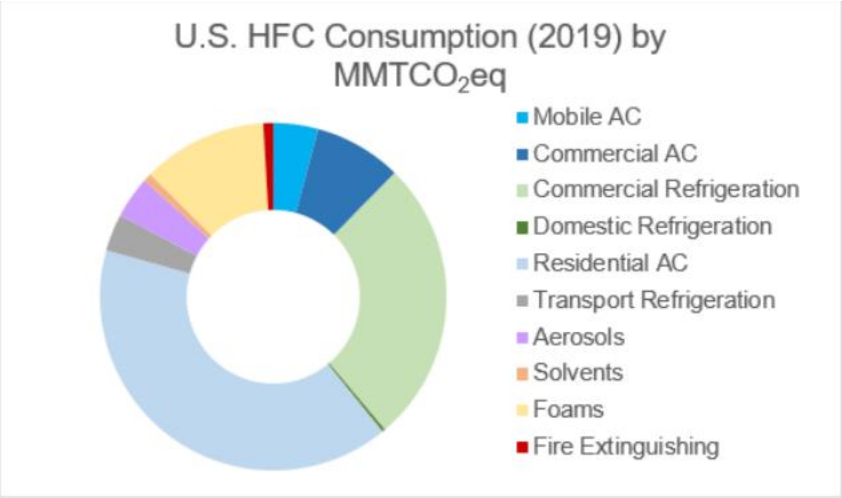

Table 1: HFC Phasedown Schedule

Year	Consumption & Production Allowance Caps as a Percentage of Baseline
2022–2023	90 percent
2024–2028	60 percent
2029–2033	30 percent
2034–2035	20 percent
2036 & after	15 percent

GWP Limit

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GWP

R-404A = 3920
R-410A = 1890
R-448A = 1273
R-513A = 573
R-134A = 1526
R-290 = 3
R-744 = 1
R-717 = 0

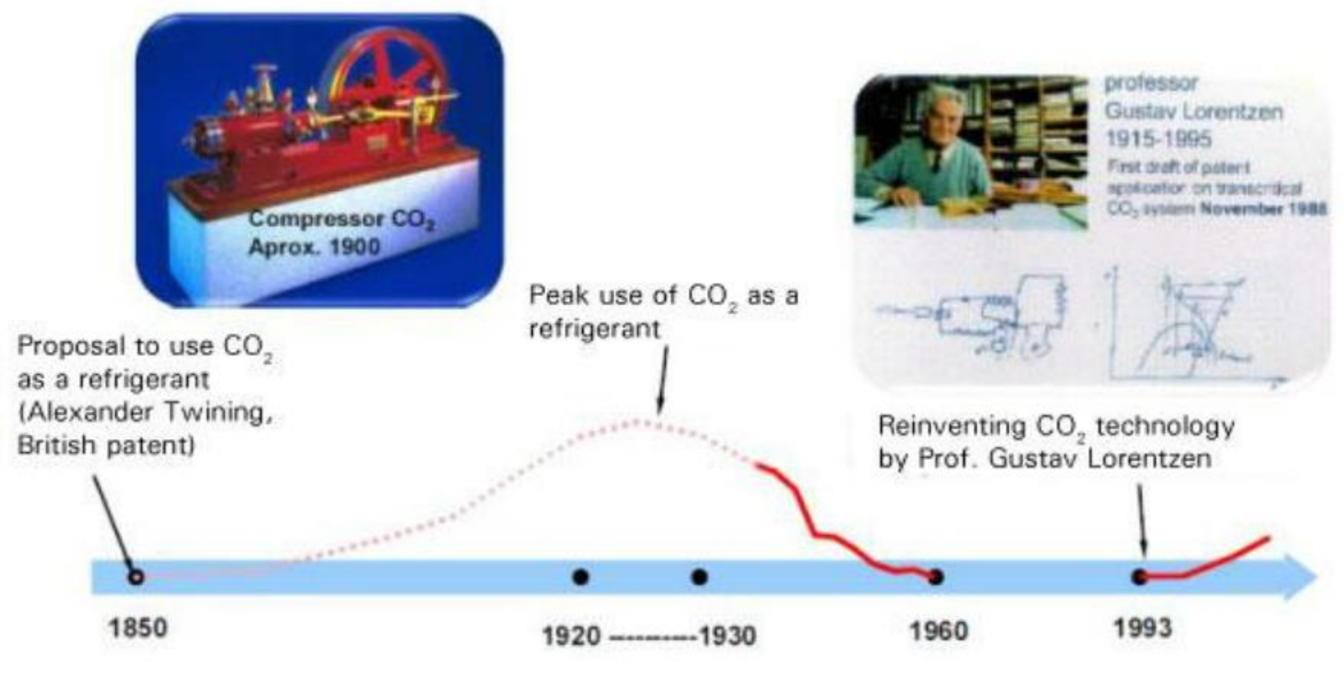
Back to Nature

sort of…

- Low GWP and ODP refrigerants have come full circle
- Ammonia, CO2, Propane are all very proven and very efficient refrigerants that are increasing in popularity due to their limited impact on the environment
- A2L's are low GWP synthetic replacements, coming very soon

CO_2

has a long history as a refrigerant



- Peaking in the 1920’s – 30’s
- Decreased in use due to the availability of CFC’s
- Renewed interest due to Environmental concerns

Benefits of CO_2 as a Refrigerant

- Lowest GWP (=1)
- High Vapor Density = Greater capacity/smaller lines and components
- 3-10X higher refrigeration capacity than synthetics
- Cheaper than synthetics ($1.5 vs $5-14 per pound)
- No reclaim required (saves time/money/equipment)
- Excellent heat exchange (good for heat reclaim and increasing system efficiency)
- Physical Stability and Safety
  - Non-Flammable
  - Non-Toxic

Challenges of CO_2 as a Refrigerant

- Gas availability (as of right now)
- Higher operating pressures
- Material considerations
- More electronics
- The “so-called” Transcritical equator
- Higher initial cost (sometimes)
- Technician familiarity

2 Main Types of CO_2 Systems

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Cascade

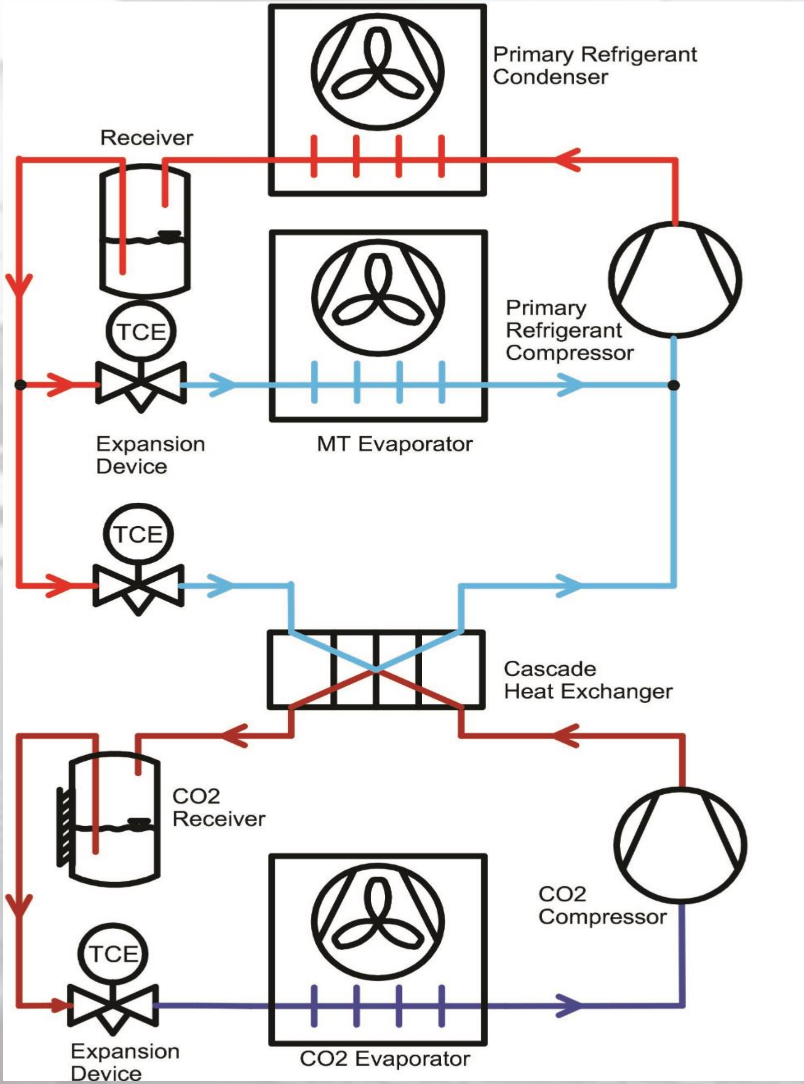
- Uses CO_2 as a secondary refrigerant to reduce the HFC charge (thus reducing overall GWP)
- The HFC portion handles the Medium Temp load while CO2 handles the low temp side
- Made in Suwanee facility

Trans-Critical (aka) Booster System

- 100% CO_2 used for both medium and low temperature applications
- ***Initially*** limited to colder areas for efficiency reasons

CO_2 Cascade

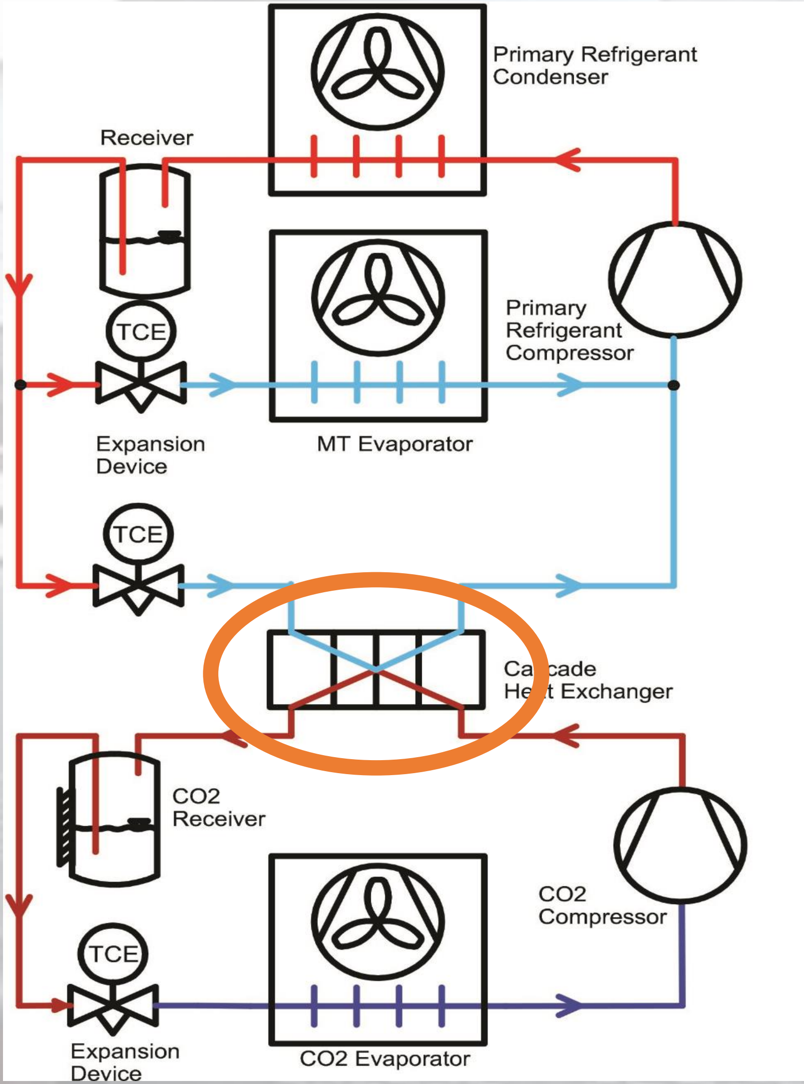
Systems



- Uses 2 types of refrigerants
- CO_2 will handle the low temperature load and is known as the secondary refrigerant
- The primary refrigerant can be whatever the customer wants (NH_3, HFC's, even glycol) will cool the medium temperature load and condense the CO_2

CO_2 Cascade

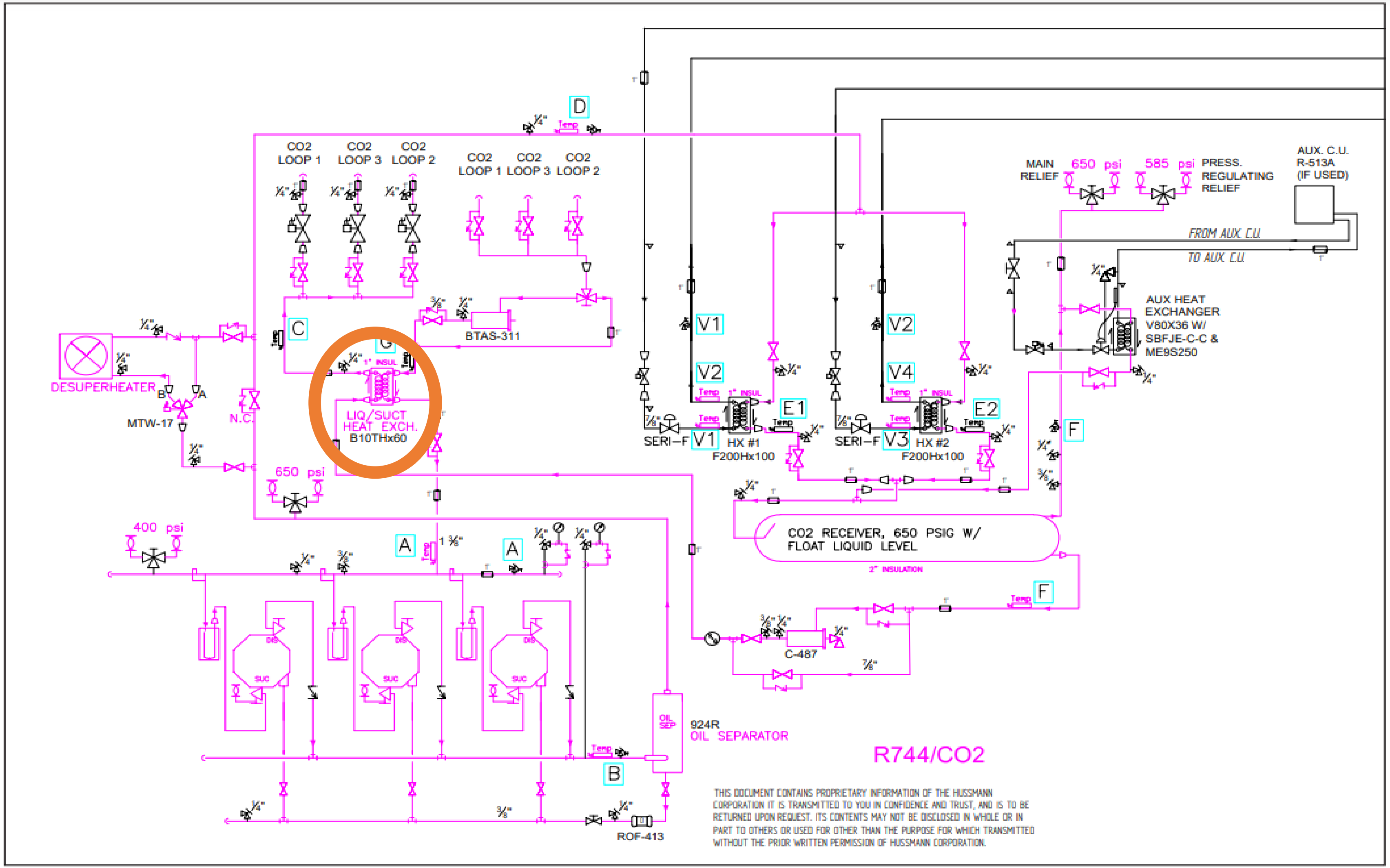
Systems



- The “Cascade” is 1, 2, or 3 heat exchangers
- Very attractive for hot climates
- Reduces the synthetic charge for the overall system
- Retrofits needs fewer new components

CO2 Cascade

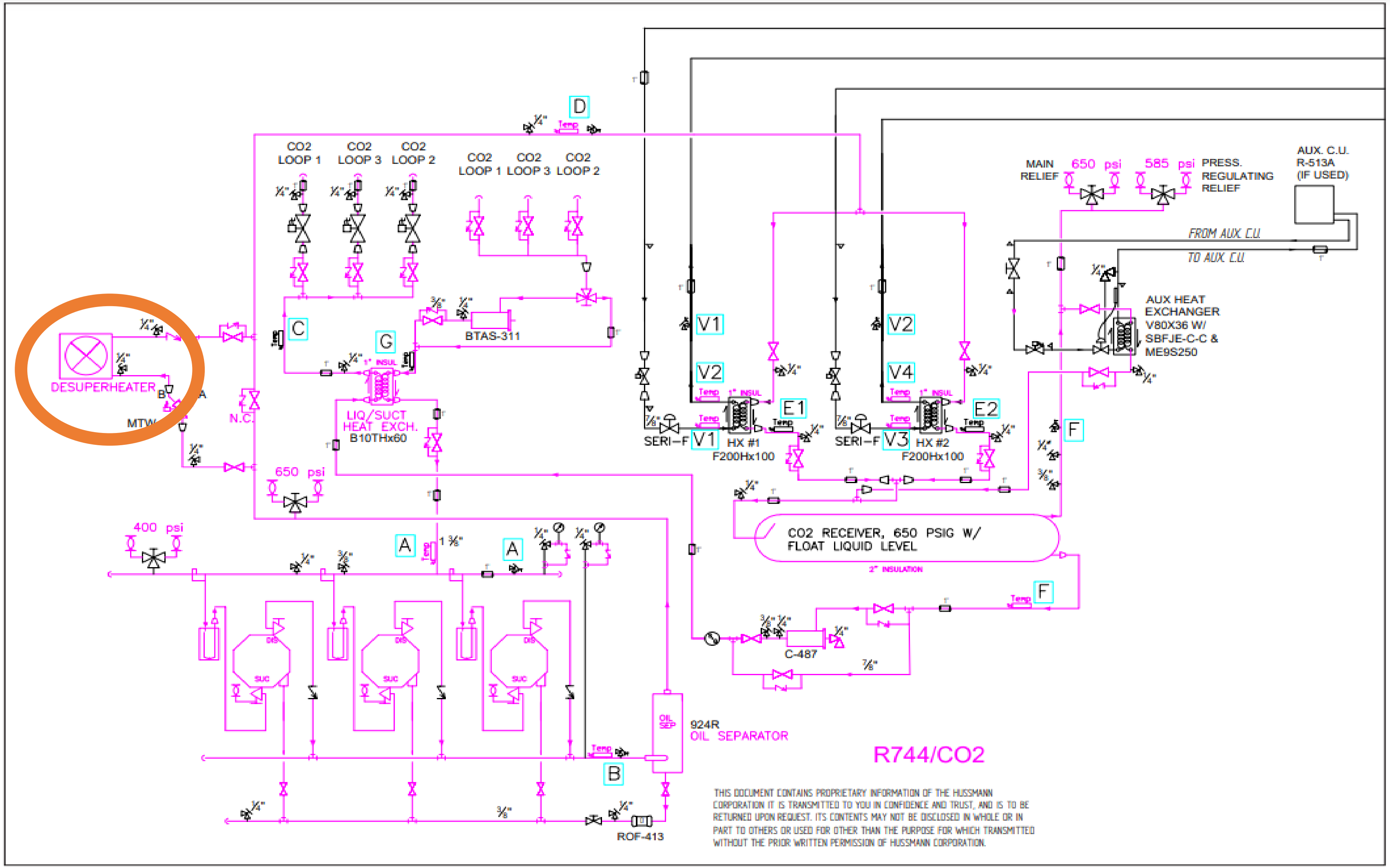
Systems



- Liquid/Suction Heat Exchanger
- Adds subcooling to liquid CO_2
- Adds superheat to the CO_2
- Compressor suction

CO2 Cascade

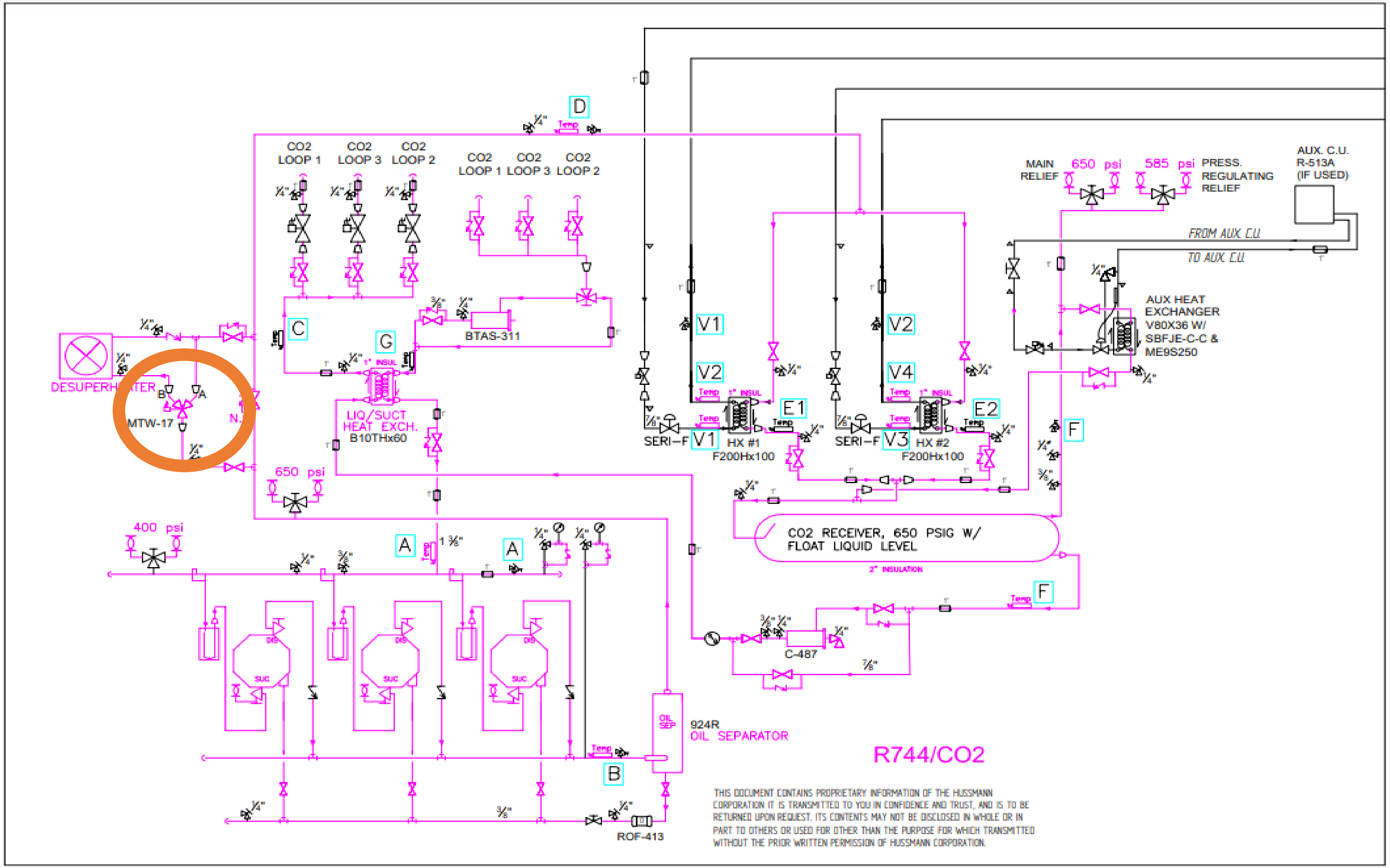
Systems



- The Desuperheater removes excess heat from the CO_2 compressor discharge
- Keeping the proper CO_2 temperature is important to maintaining cascade function

CO_2 Cascade

Systems



- Modulating 3 Way Valve
- Changes the amount of CO_2 going to the desuperheater to maintain the proper temperature going to the cascades
- Cascade inlet set point is around 105-115F

CO_2 Cascade

Systems

'B' PORT is going to the Desuperheater

'A' PORT is the bypass

Serviceable type

- Modulating 3 Way Valve
- Sends gas to either the desuperheater or a bypass
- If improperly piped or programed, it can cause CO_2 condensation before the cascade
- This can cause system performance issues

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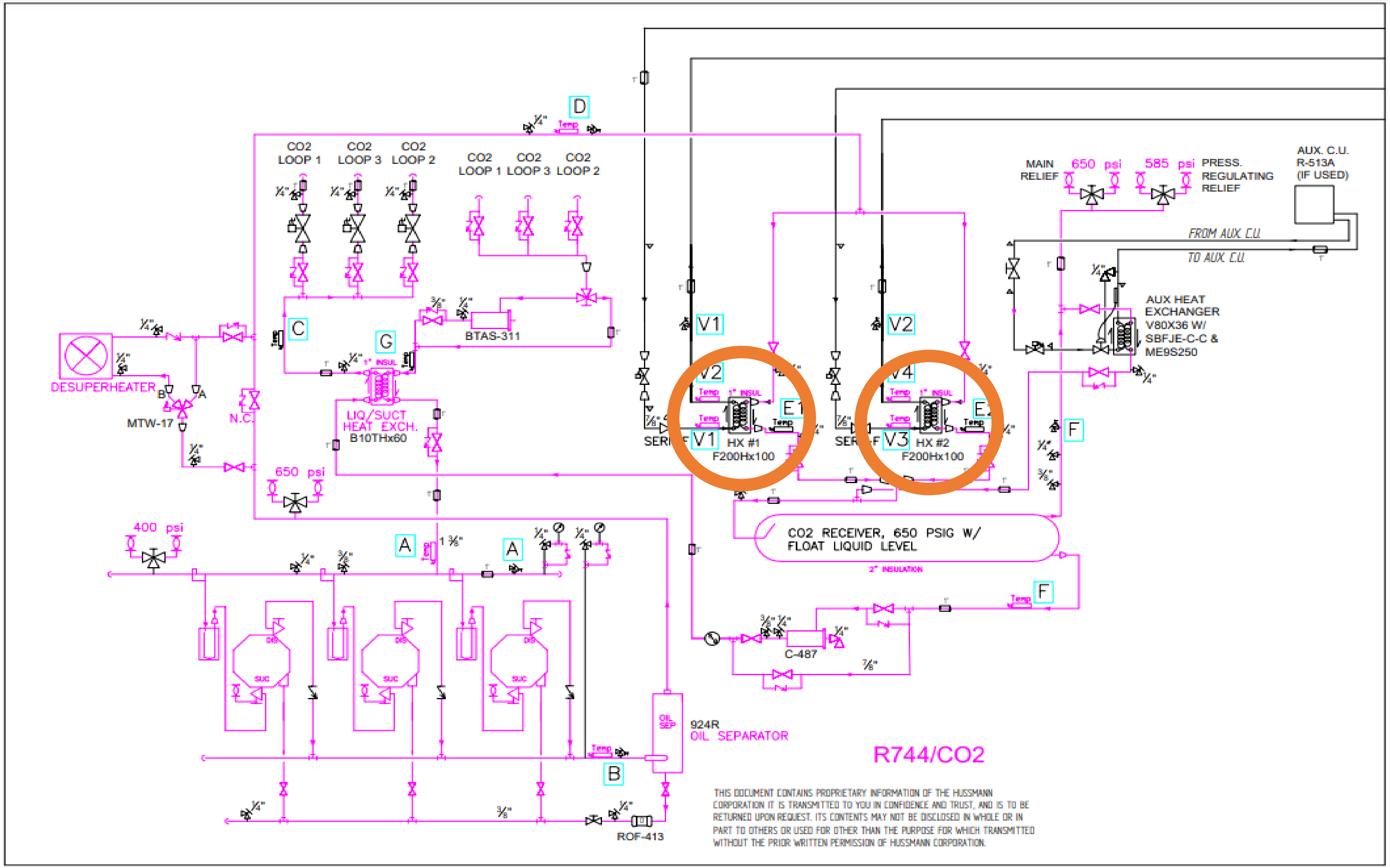
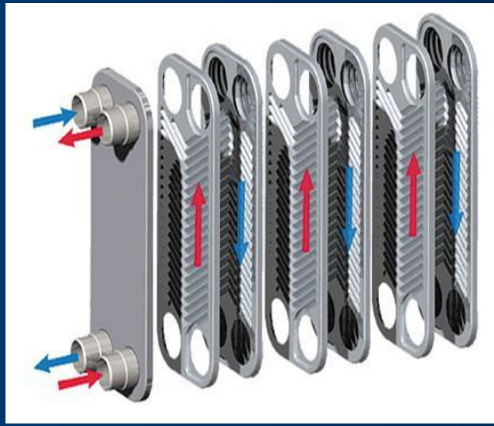
CO_2 Cascade

Systems

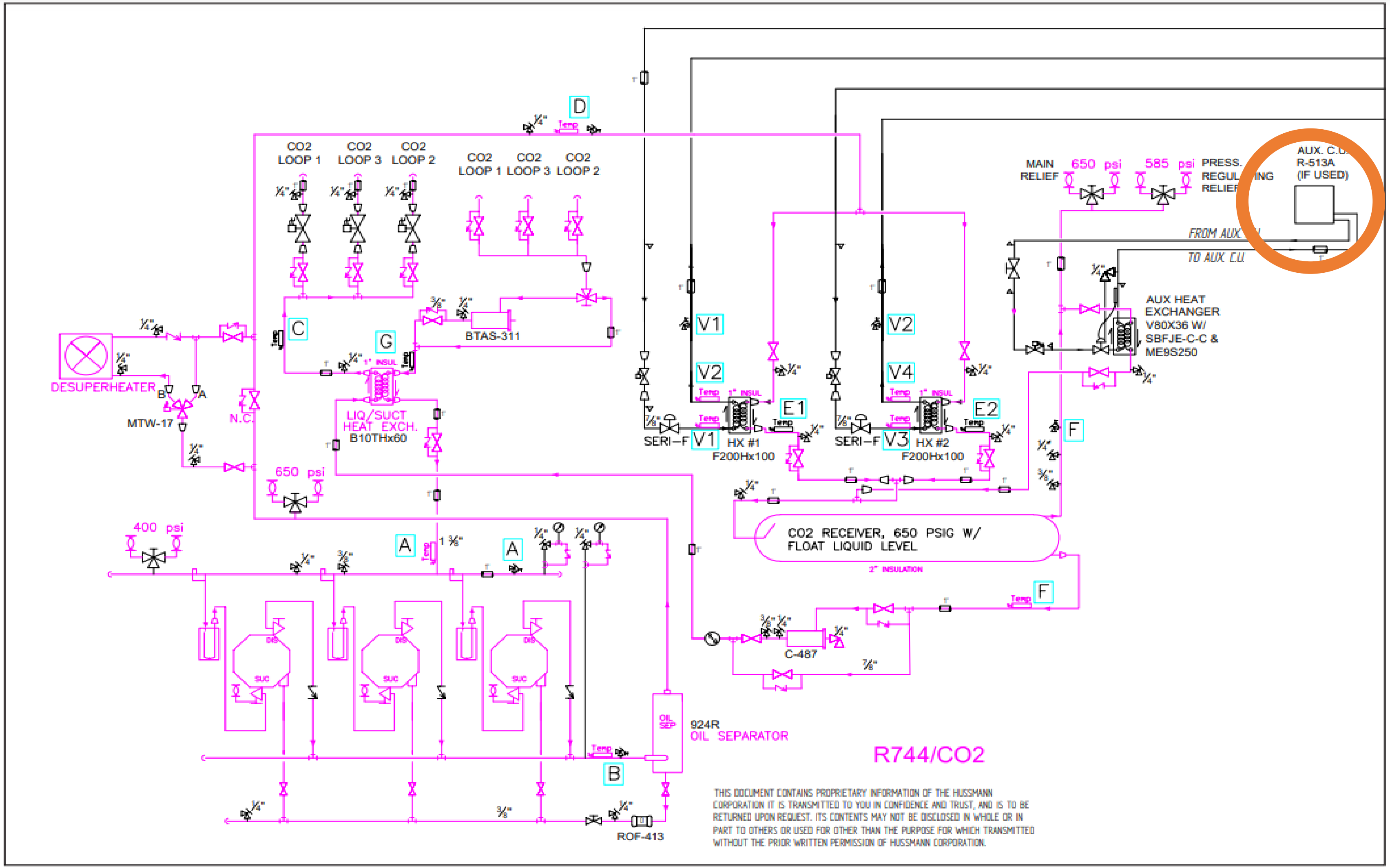


- The Cascades
- This is where the CO_2 is condensed by the primary synthetic refrigerant
- Standard plate heat exchanger



CO2 Cascade

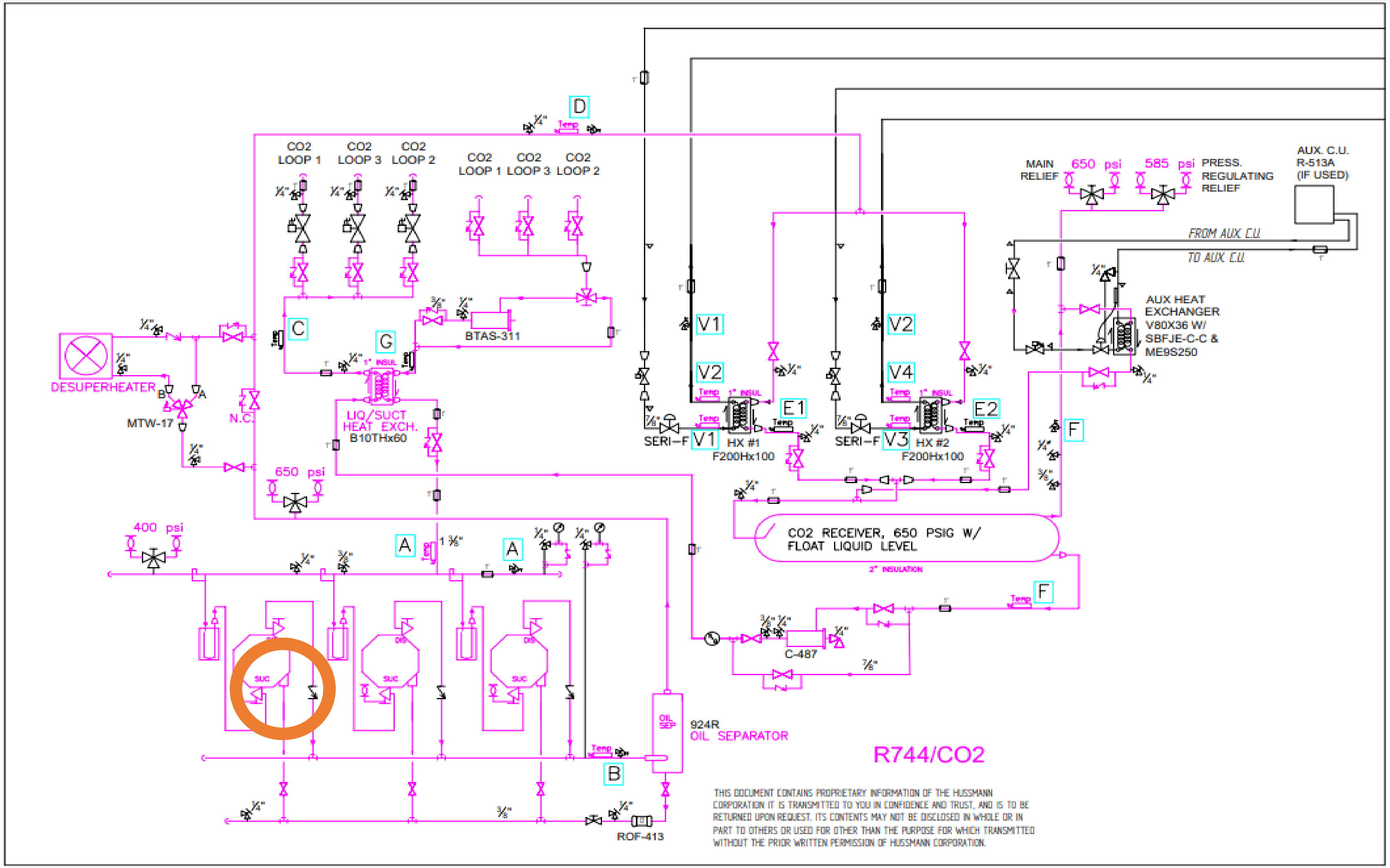
Systems



- Auxiliary Condenser
- Hooked to EPS
- In the event of a power failure, it will circulate and cool CO_2 from the receiver
- This prevents relief valves lifting and lost charge

CO2 Cascade

Systems



- CO_2 compressors use the Emerson OMC to maintain oil level
- The HFC compressors use Sporlan

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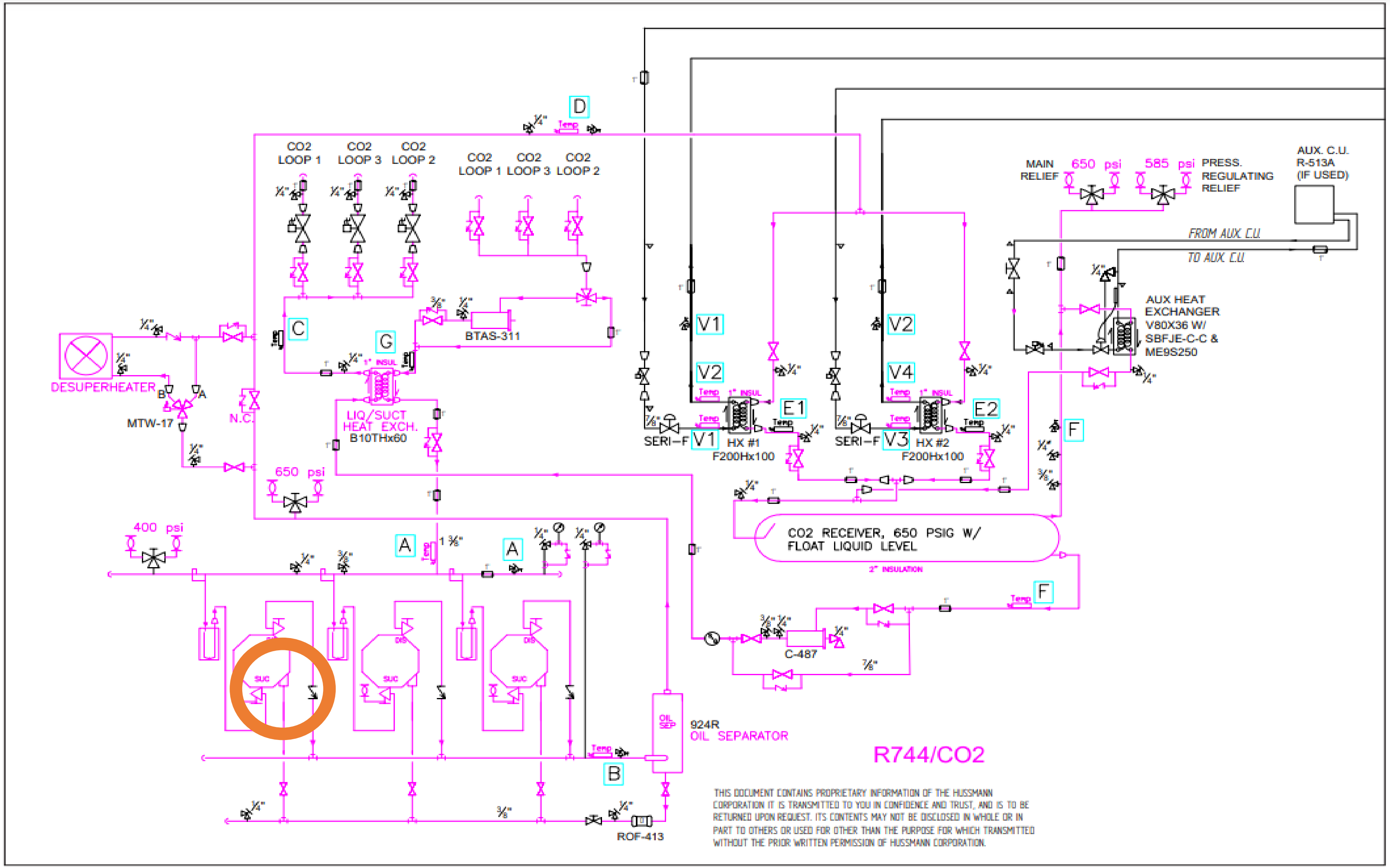
CO_2 Cascade

Systems

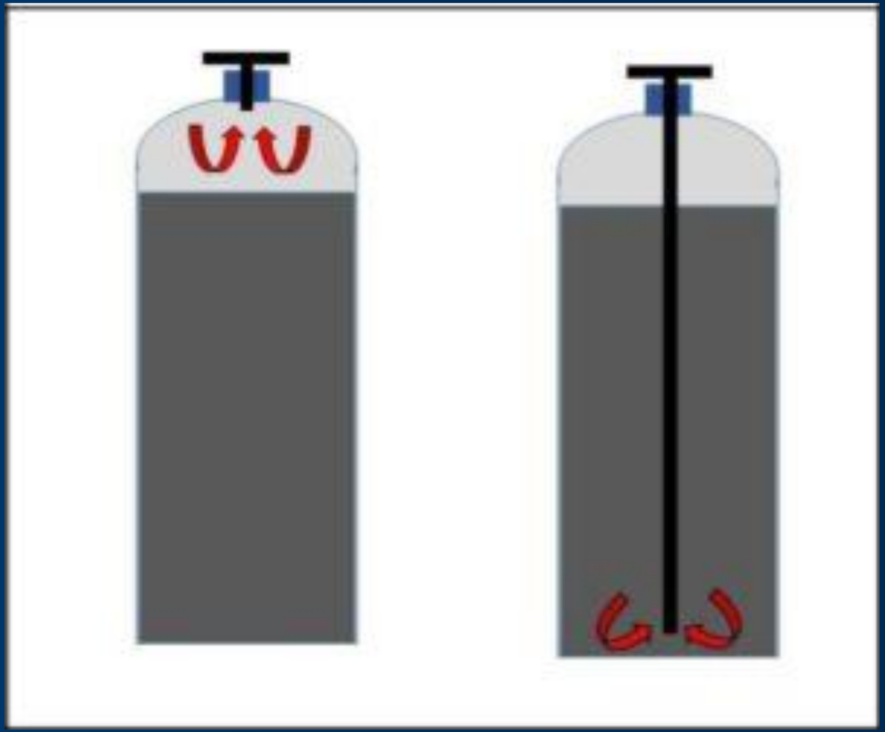


- Suction Filters
- It is recommended to leave the filter in after start up on CO_2 systems
- They should be changed during during PM

A Word About Charging CO_2

CO_2 Vapor Cylinders

- CO_2 vapor cylinders are the more commonly available cylinder type and are required to break vacuum and pressurize the system to 150 psig.
- Dry ice will form inside the system if the system is not pressurized to 150 psig before liquid charging.
- When selecting a CO_2 cylinder ensure that it is the correct type and grade before using.

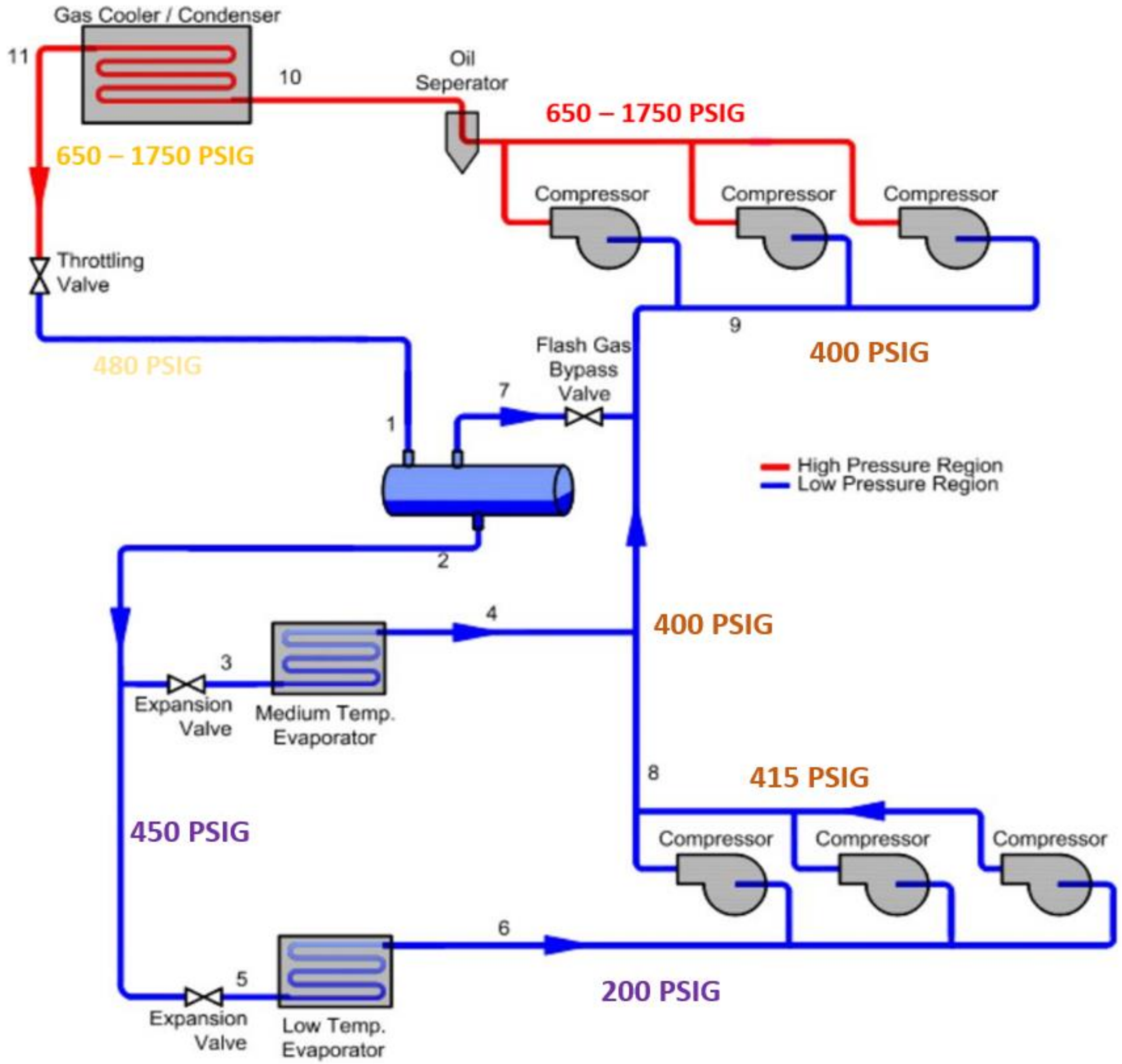


CO_2 Liquid Cylinders (w/dip tube)

- CO_2 liquid is required for charging the remaining volume, reference refrigeration legend for estimated charge.
- Tank must be identified as having a “dip tube” or “siphon tube” to extract liquid from the cylinder
- Try to use 50 lb. Tanks**

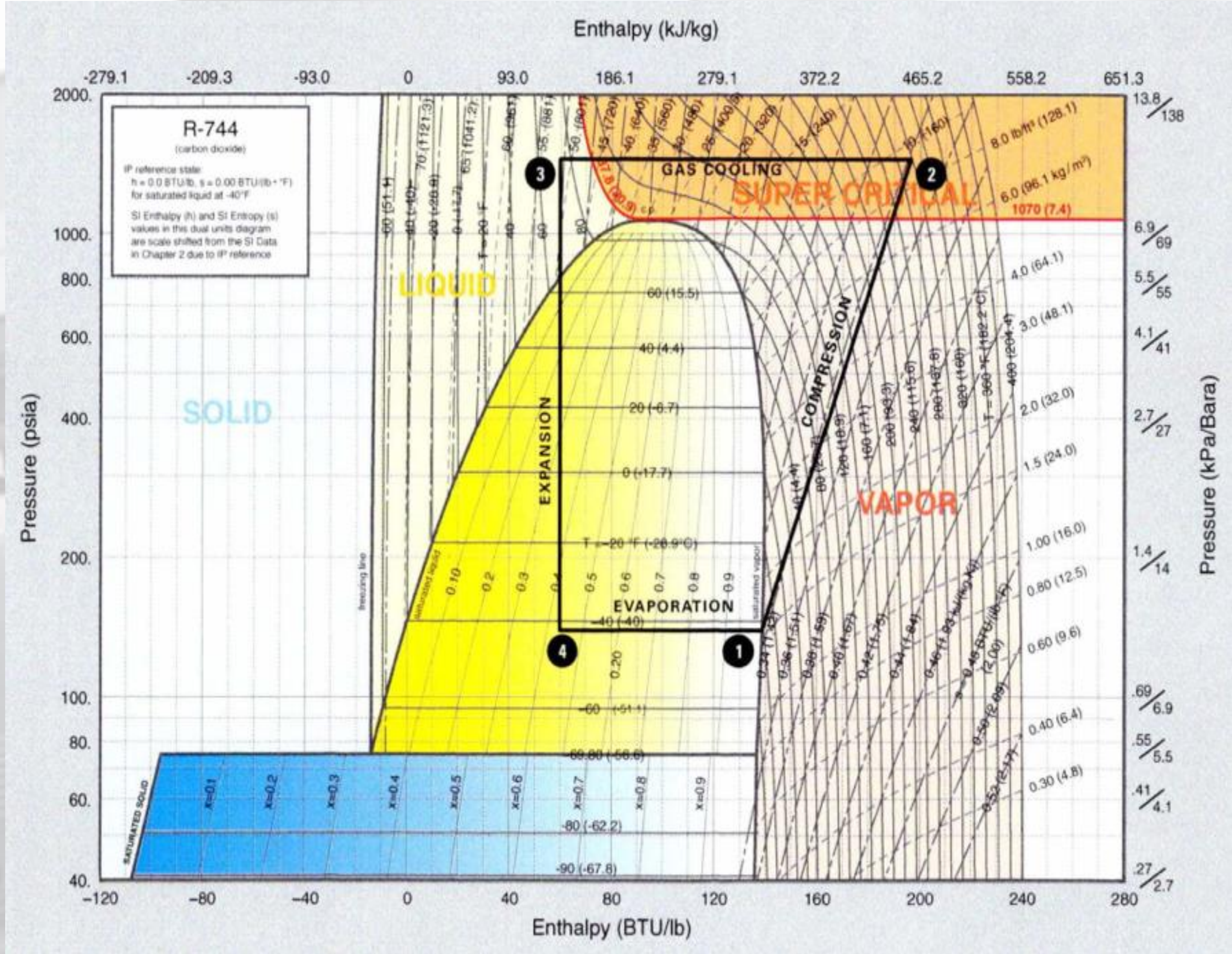
**Phase change using only pressure change

Transcritical Systems



Transcritical

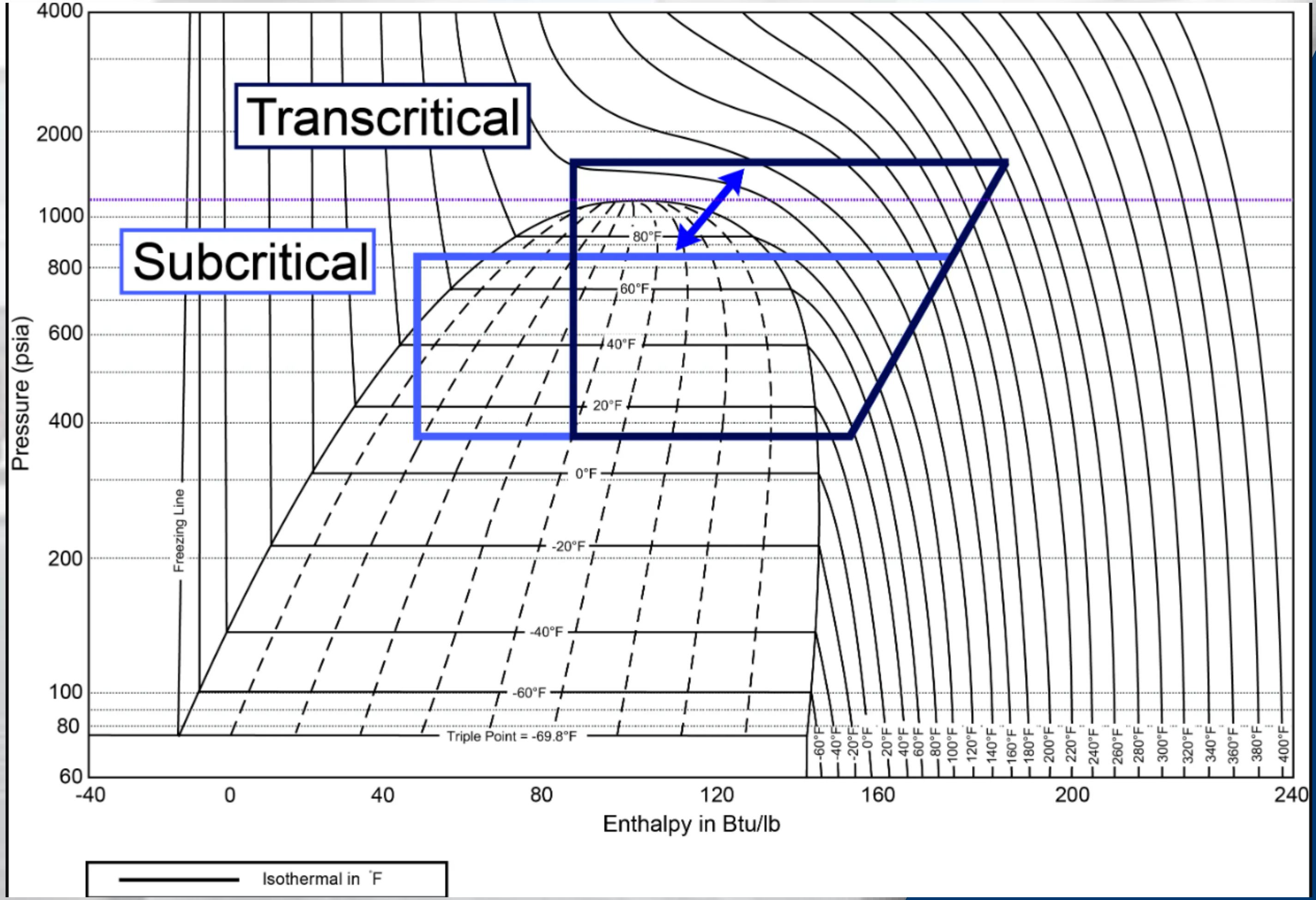
Systems



- Every substance has a “critical point”. Above this certain pressure and temperature, the linear relationship between those values breaks down
- Just removing heat will not condense the refrigerant
- Remember: The refrigerant must be a liquid in the cases because it needs to boil to remove heat!
- BUT, decreasing the pressure to below the critical point will condense the refrigerant
- This phenomenon is known as ***transcritical operation*** and is the ***major difference*** between 100% CO_2 systems and other types (cascade or direct expansion)

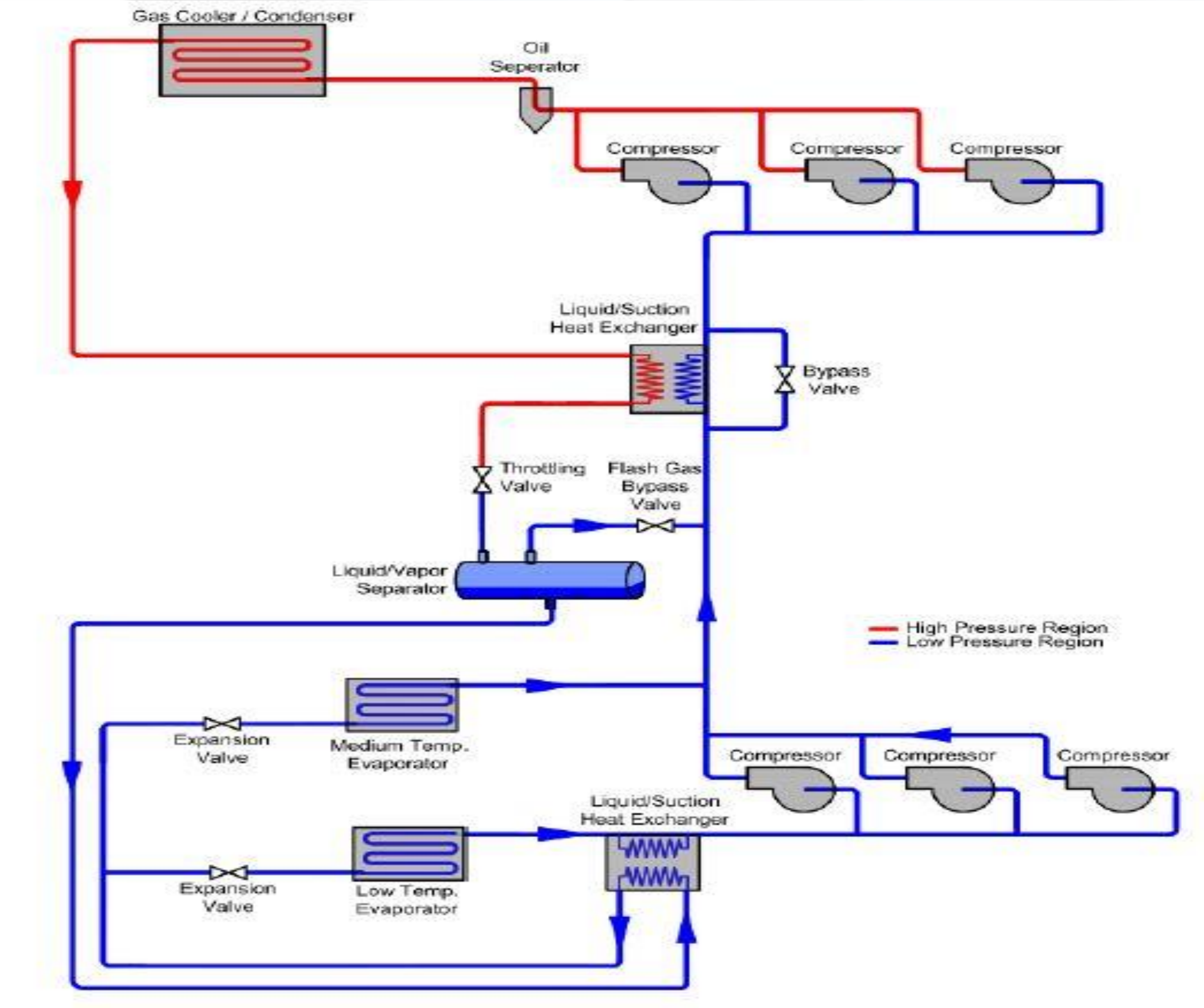
Transcritical

Systems



- In Sub-Critical operation, the condenser does just that, condenses the refrigerant by simply removing heat.
- In Trans-Critical operation (ambient temperature above 88F) The CO_2 can't condense just by the removal of heat, so the gas is cooled only.

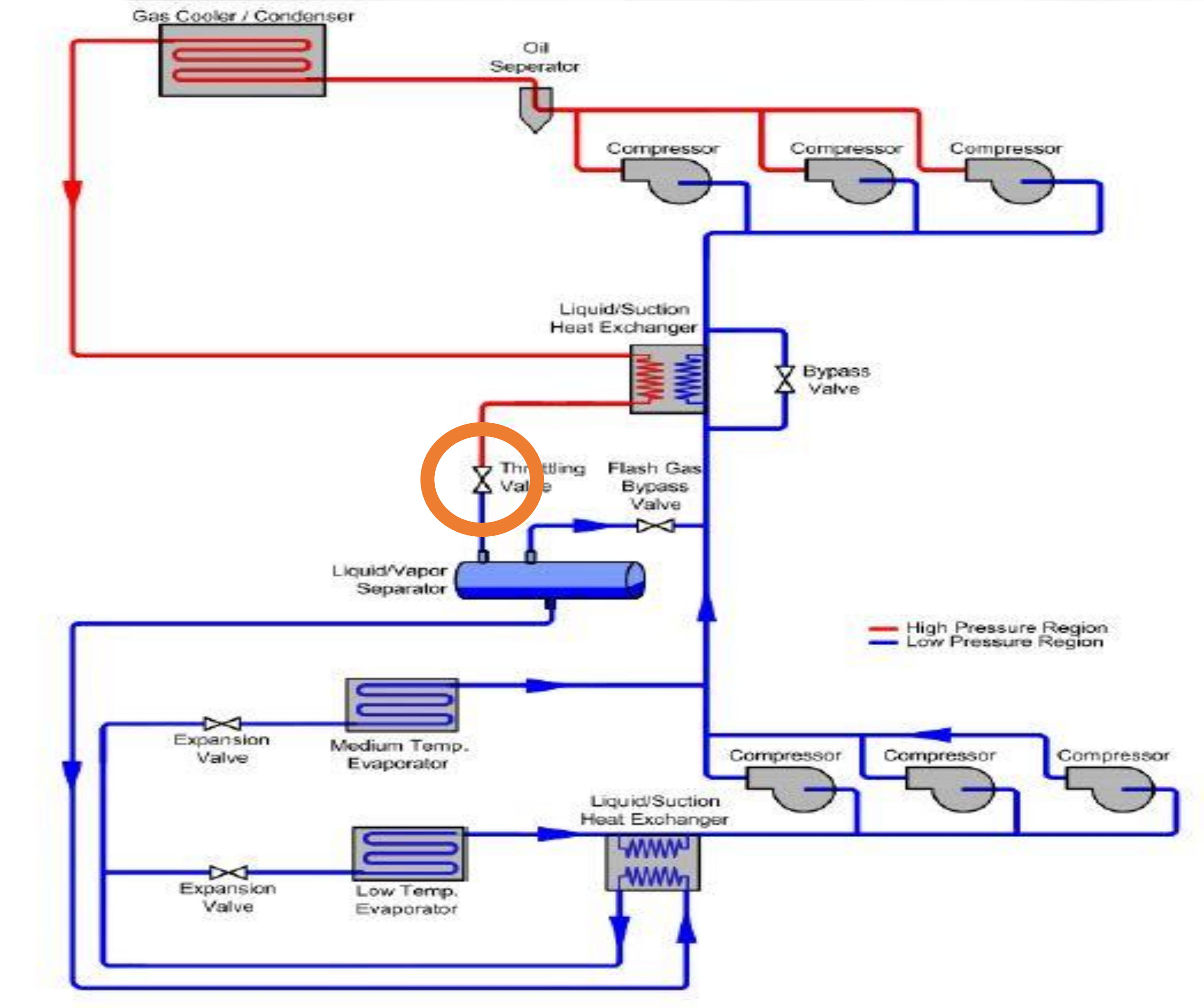
Transcritical
Systems



- Two modes of operation
  - Sub-critical & Trans-critical
- Two groups of compressors
  - Low Temp & Medium Temp
- High operating pressures
- Low-cost refrigerant
- Regulation proof
- More controls/electronics
- Only one fluid to as opposed to cascade systems

Transcritical

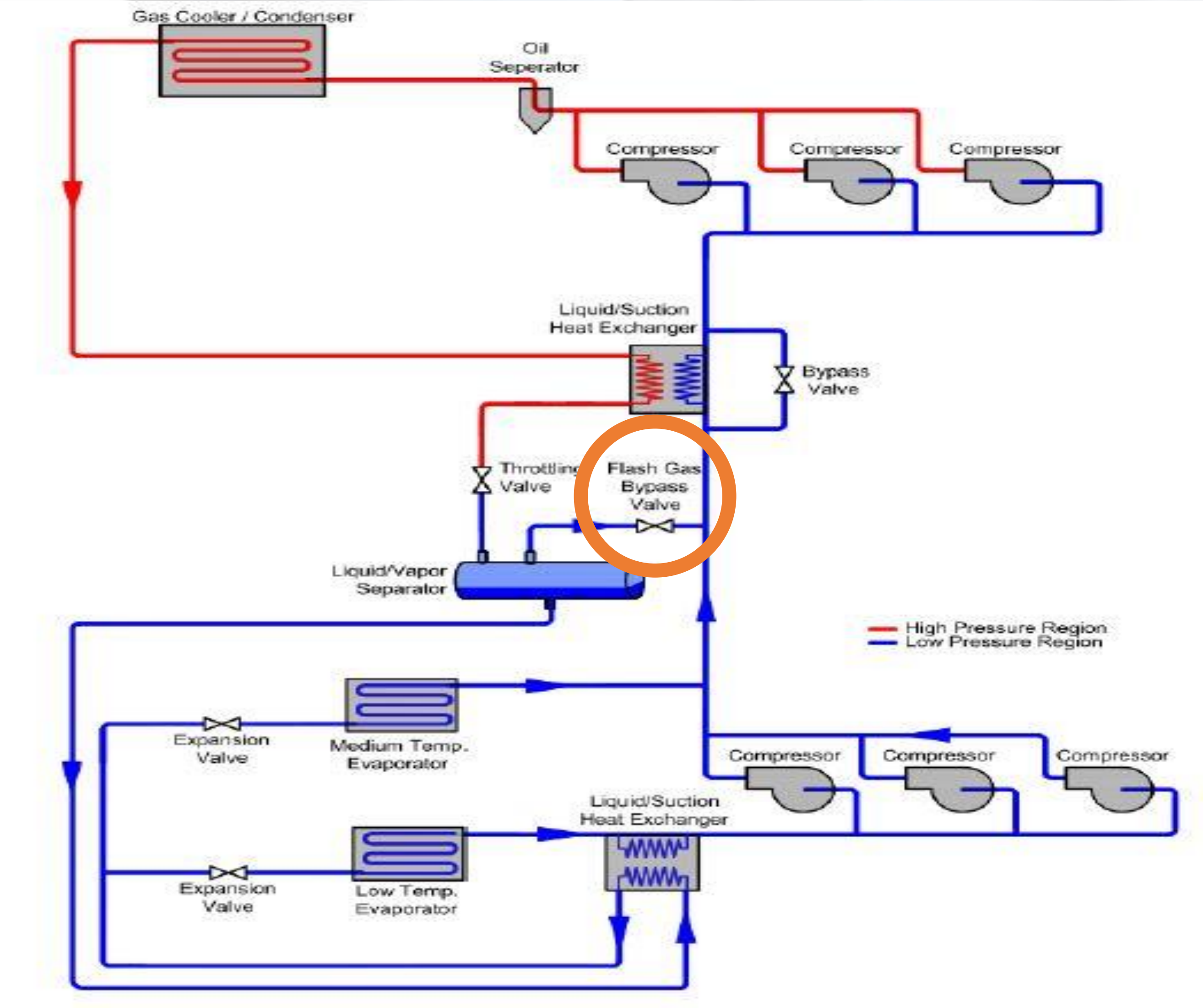
Systems



- In transcritical operation there is no liquid refrigerant leaving the gas cooler
- The throttling valve will reduce the pressure, forcing a state change for a portion of the refrigerant
- Depending on gas cooler outlet pressure and temperature, the liquid-vapor mix can be 50-50, 60-40, 70-30 etc.

Transcritical

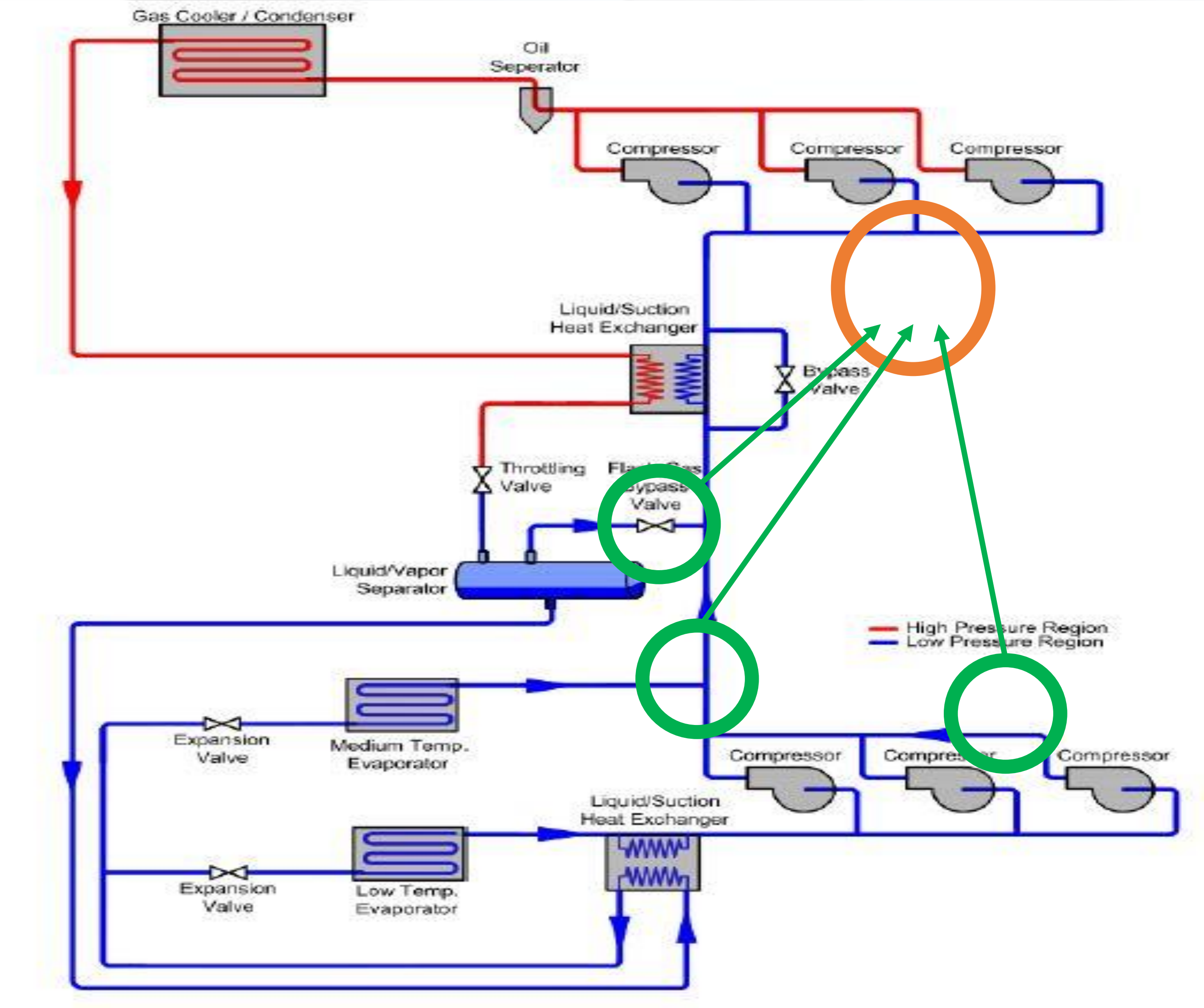
Systems



- As more vapor enters the flash tank, the pressure rises, and the flash tank bypass valve opens to relieve it.
- This refrigerant has been compressed but has done no cooling, resulting in a decrease of system efficiency
- The vapor mixes with the rest of the compressor suction to be compressed again

Transcritical

Systems



- Transcritical systems are unique because they draw compressor suction from 3 sources
- This results in a highly dynamic environment where pressure, temperature and mass flow are regularly changing
- Superheat control is ***very*** important on CO_2 systems

Transcritical

Systems

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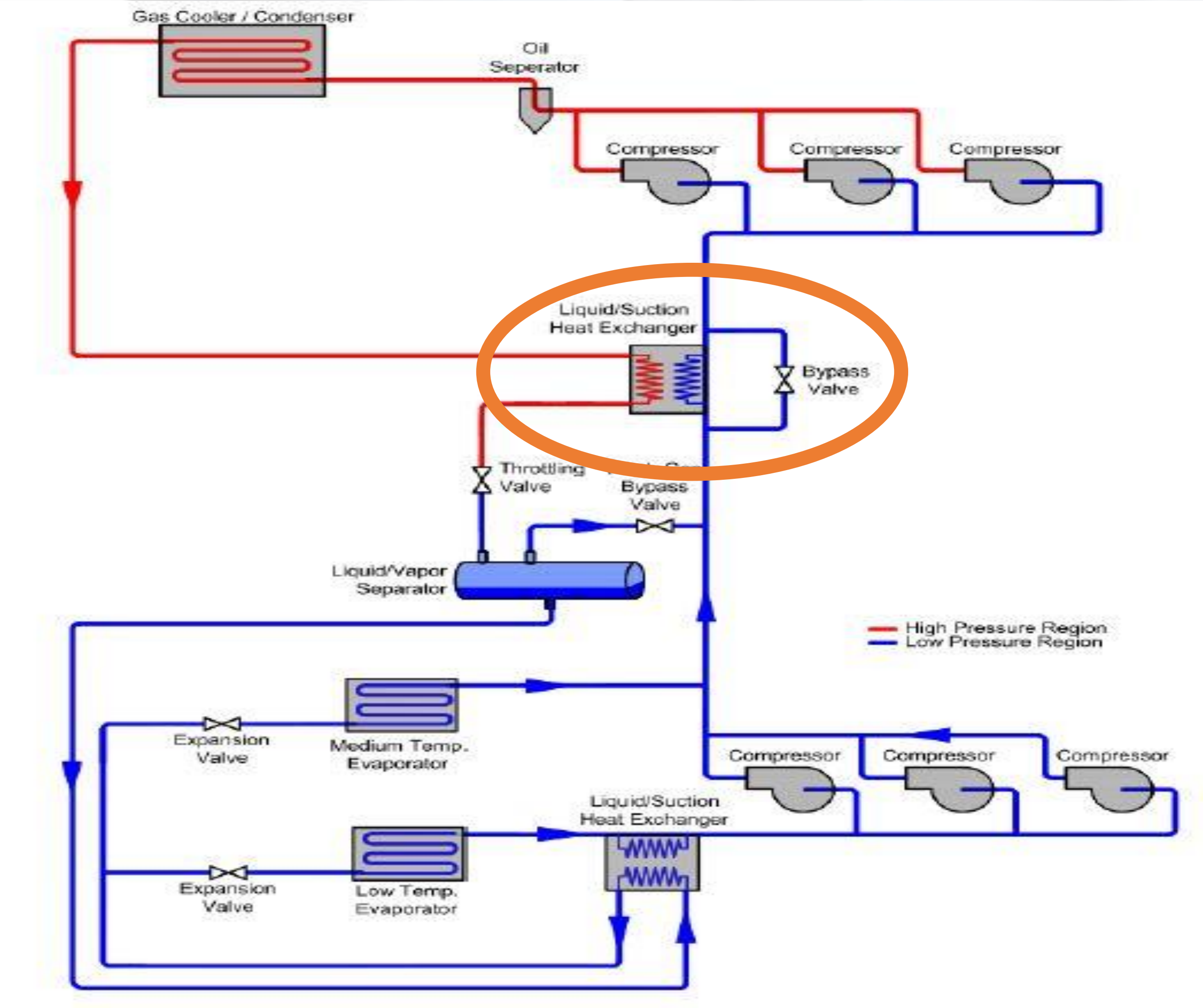

- Superheat control is ***very*** important on CO_2 systems
- If SH is too low, the system will begin pulling oil because of CO2s chemical properties
- If SH is too high, the oil will degrade resulting in poor lubrication and compressor wear

Transcritical

Systems

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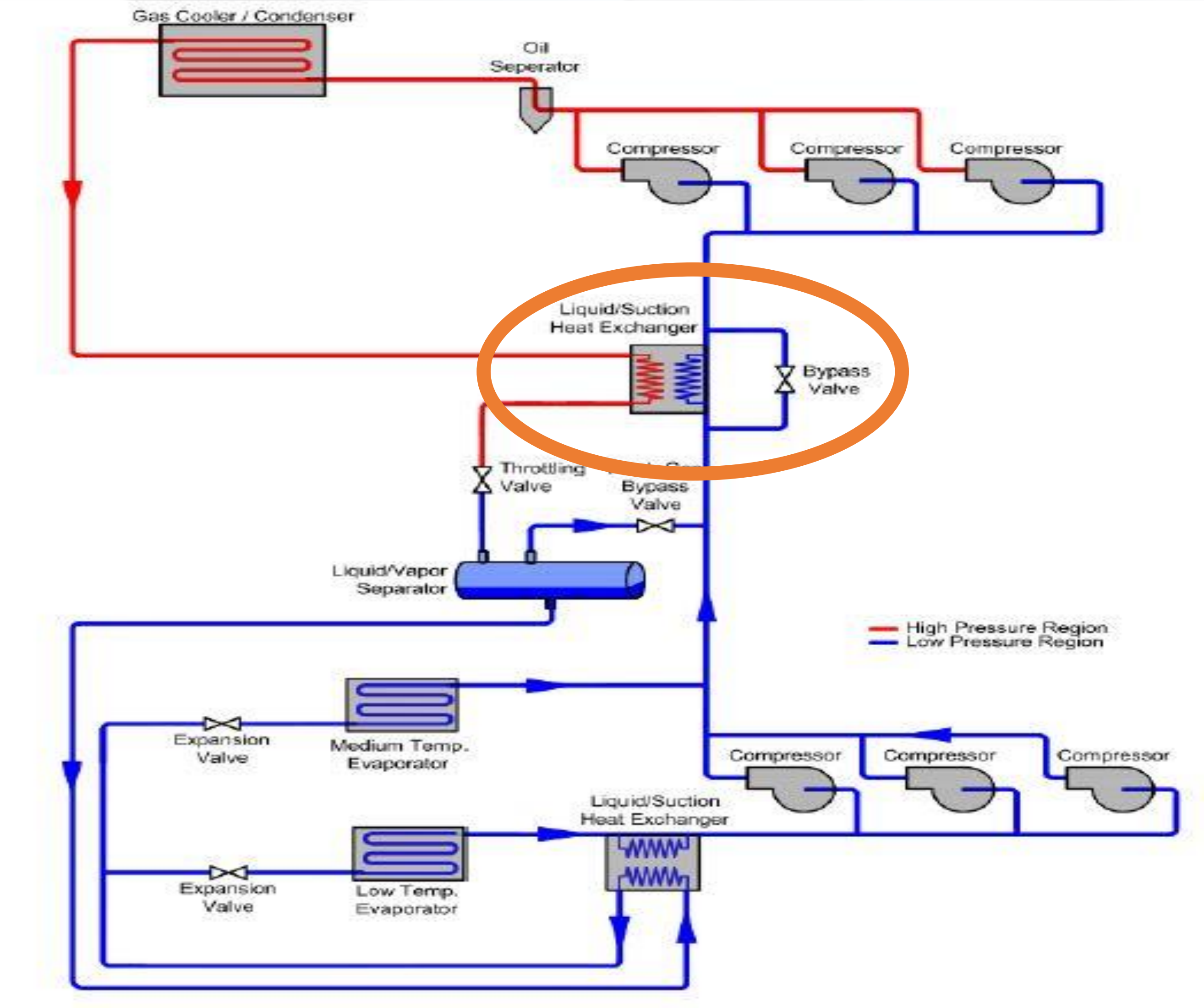

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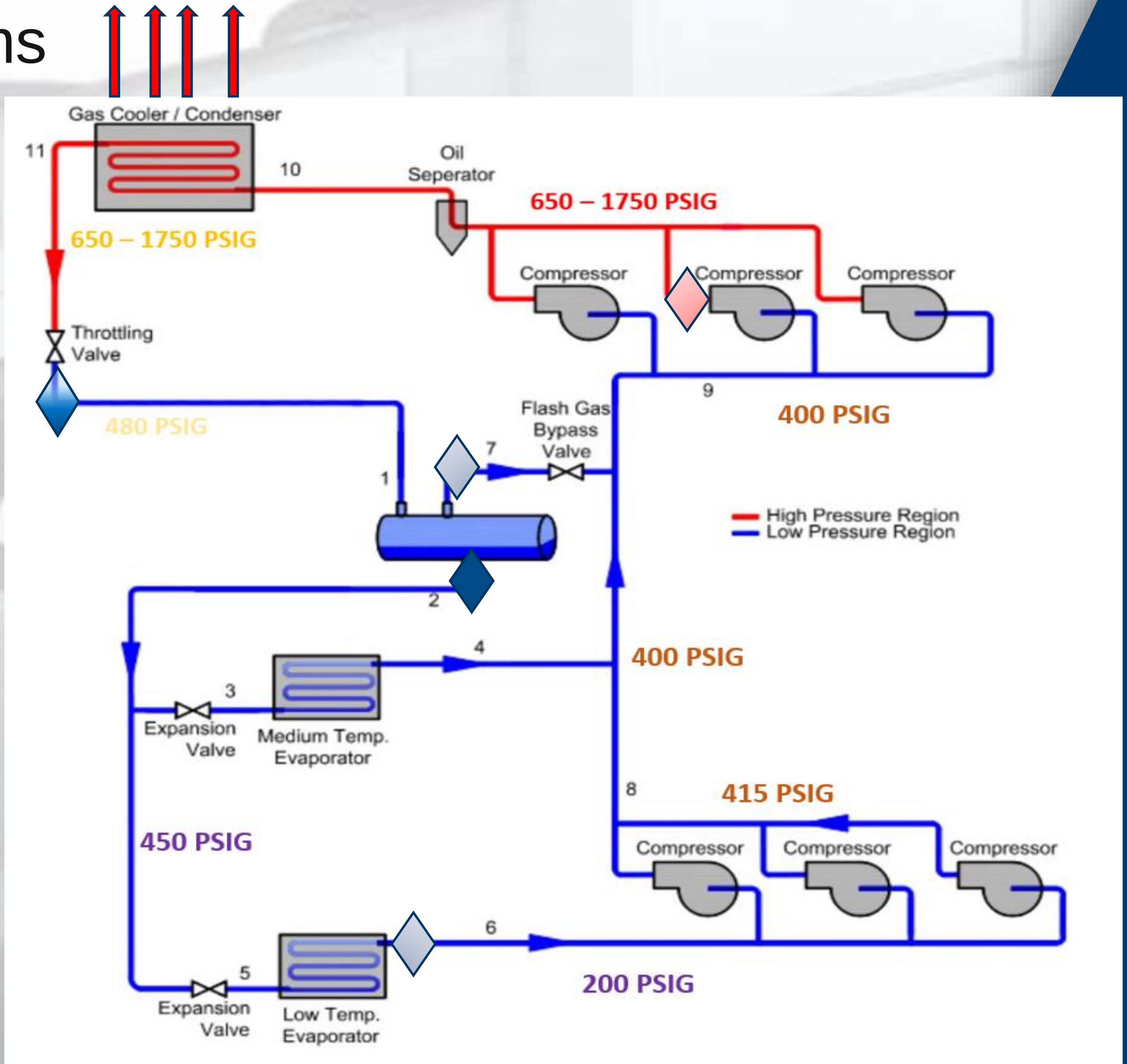
Transcritical

Systems



- Liquid/Vapor mix
- Liquid
- Low Pressure vapor
- High Pressure Vapor

Heat rejected to atmosphere

Improving Efficiency

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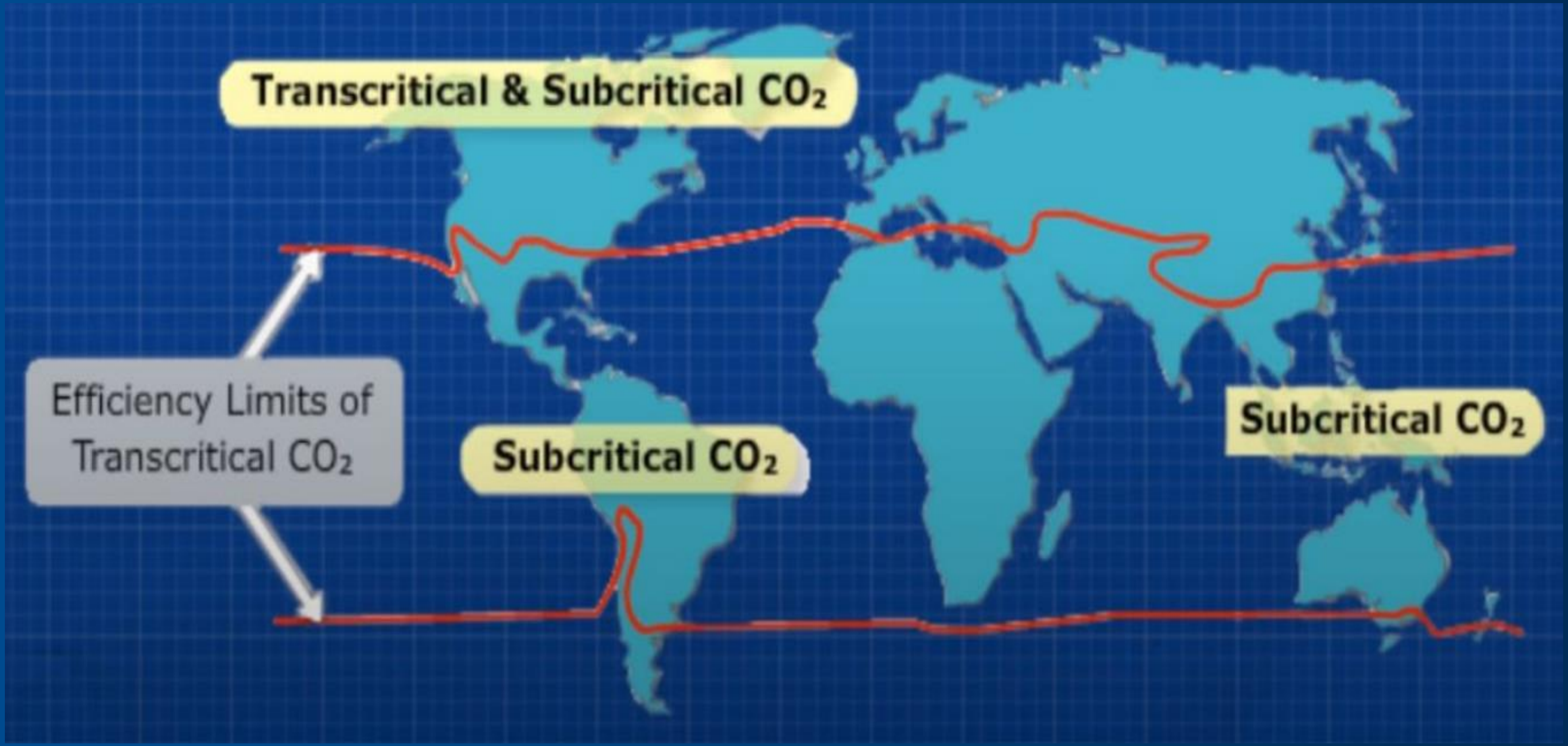
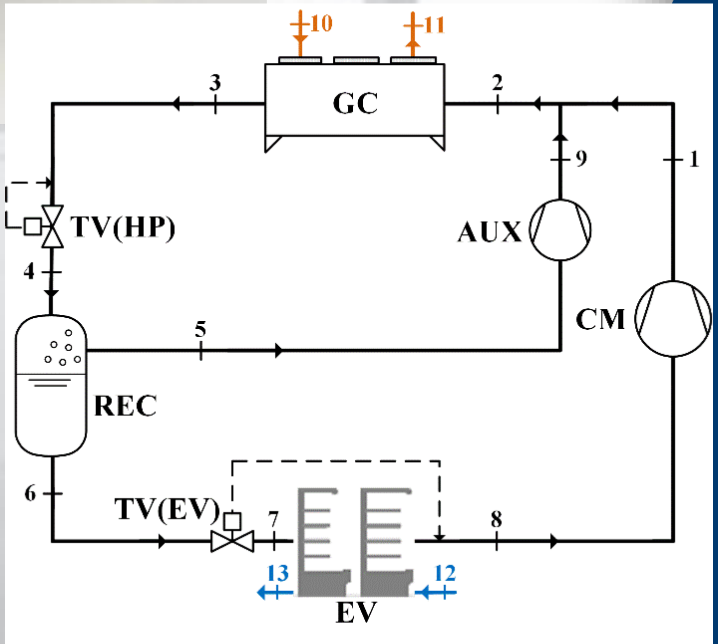
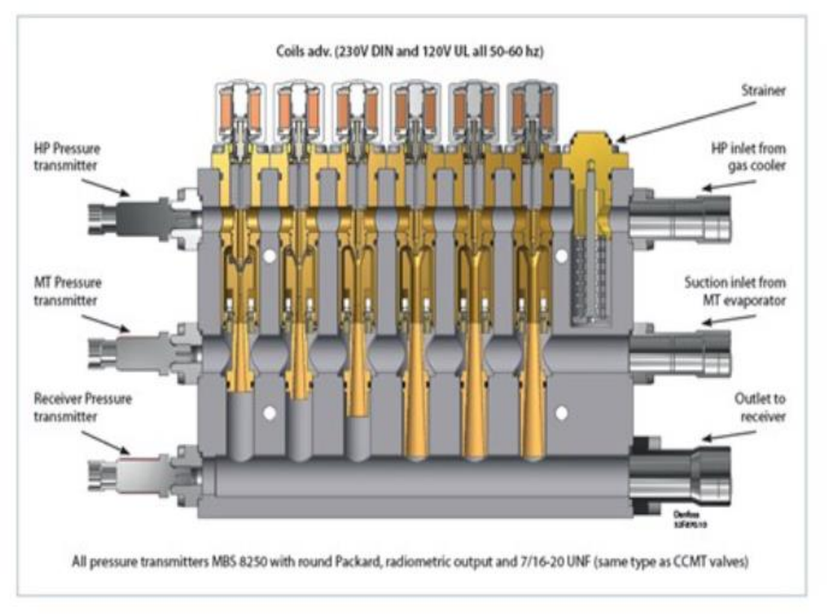


Traditionally, Transcritical systems in hotter climates paid a significantly high energy penalty which made them financially unfeasible. BUT THAT WAS THEN…..

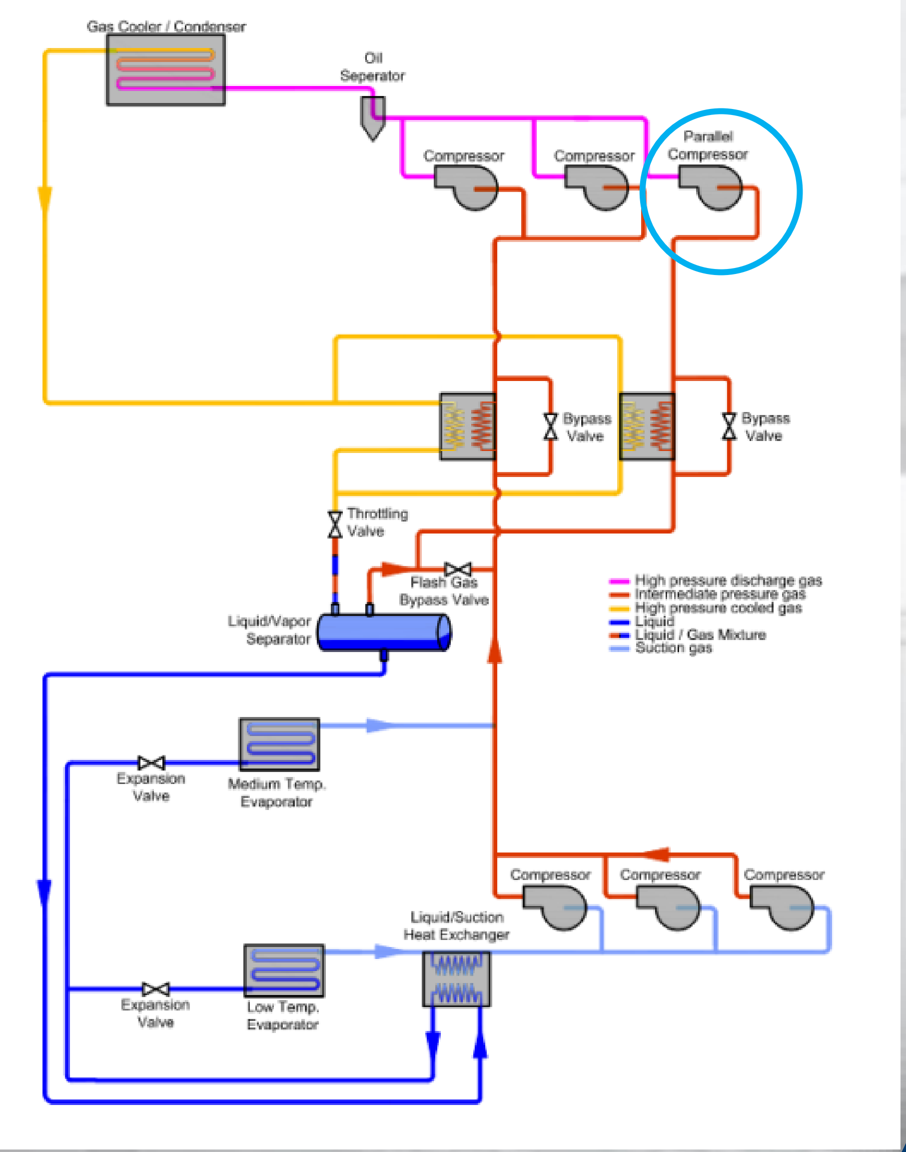
Improving Efficiency





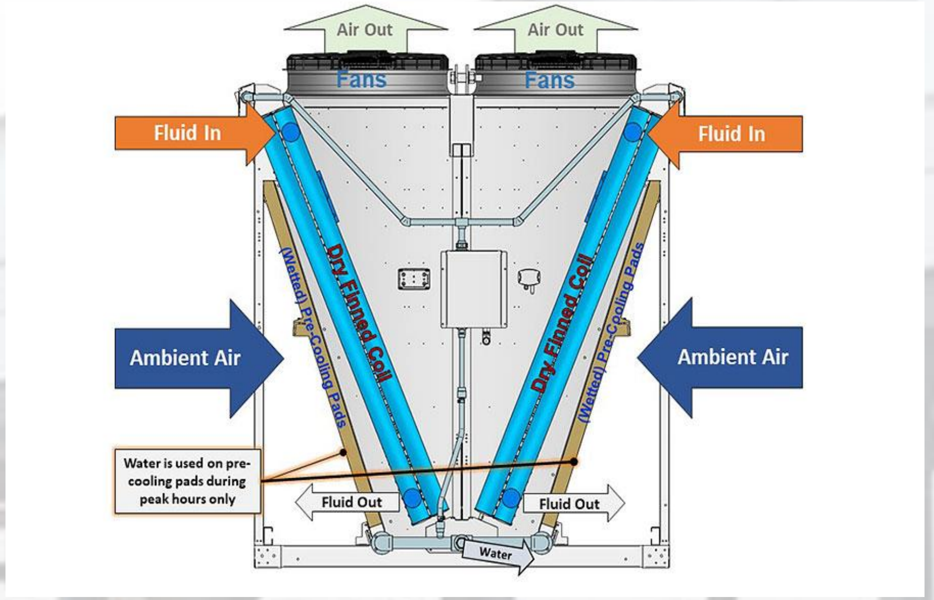
- Parallel Compression
- Adiabatic Gas Coolers
- Multi-Ejectors

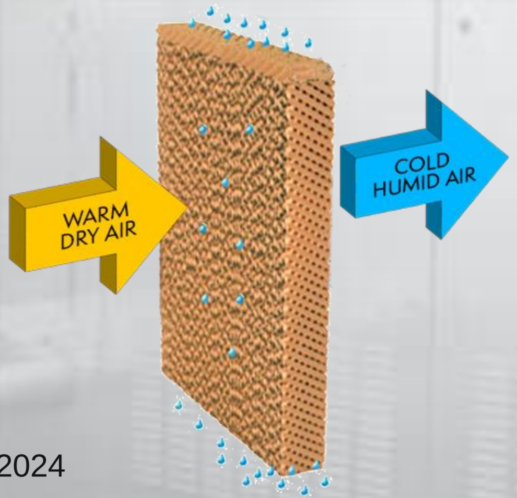
Parallel Compression

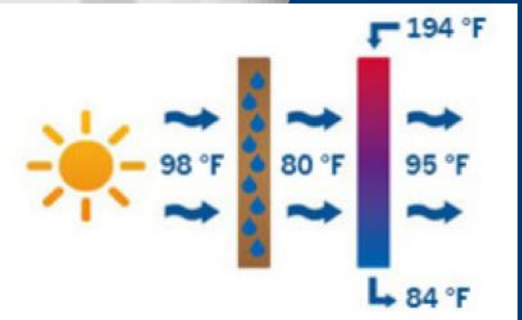


- Uses a dedicated compressor for handling flash gas leaving the flash tank
- Reduces overall compressor load allowing for smaller or fewer compressors
- Example: instead of three 15HP compressors, we now need only 2 and a smaller 5 HP to handle flash gas.
- In this example, the parallel compressor saves 25% electricity

Adiabatic Gas Coolers







- Uses wet "pre-cooling" pads to cool the incoming ambient air, allowing for greater heat rejection
- Works best in hot dry climates
- Decreases trans-critical hours, thus reducing the energy penalty
- Study: Palm Springs, CA
  - Without adiabatic cooling the system was TC for 54.7% of the time
  - WITH adiabatic cooling the system was TC for only 5.6% of the time

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Multi-Ejectors

- Takes the place of the HPV or throttling valve
- Mixes gas cooler discharge with a portion of main compressor suction gas
- Reduces main compressor load and increases suction pressure
- Works best with a parallel compressor and in hot climates (need high gas cooler discharge pressure)

The Future

- Increased Adoption and Use of Natural Refrigerants (CO_2 and Propane)
- Continued improvements with efficiency (Parallel C, Ejectors, etc.)
- Regulation will continue to push against synthetics
- EPA estimates that stores lose, on average, 25% of their charge each year (the equivalent of emissions from 12.5 million cars)
- Refrigeration and Air conditioning account for 17% of global electricity usage

Thank You!

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CO_2

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