

Natural Refrigerant Training Summit

Building a Sustainable Workforce

CO₂ : 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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North American Sustainable Refrigeration Council (NASRC)

Mission Create sustainable future for supermarket refrigeration by removing barriers to natural refrigerant adoption

➤ **501c3**
Non-Profit Organization

➤ **150+**
Members

➤ **51,000+**
Food Retail Locations

Goals

- **Build sustainable workforce**
- Increase funding options
- Increase education & awareness

Natural Refrigerants

Carbon Dioxide
R744

Propane
R290

Ammonia
R717

Need help? Look for NASRC staff!



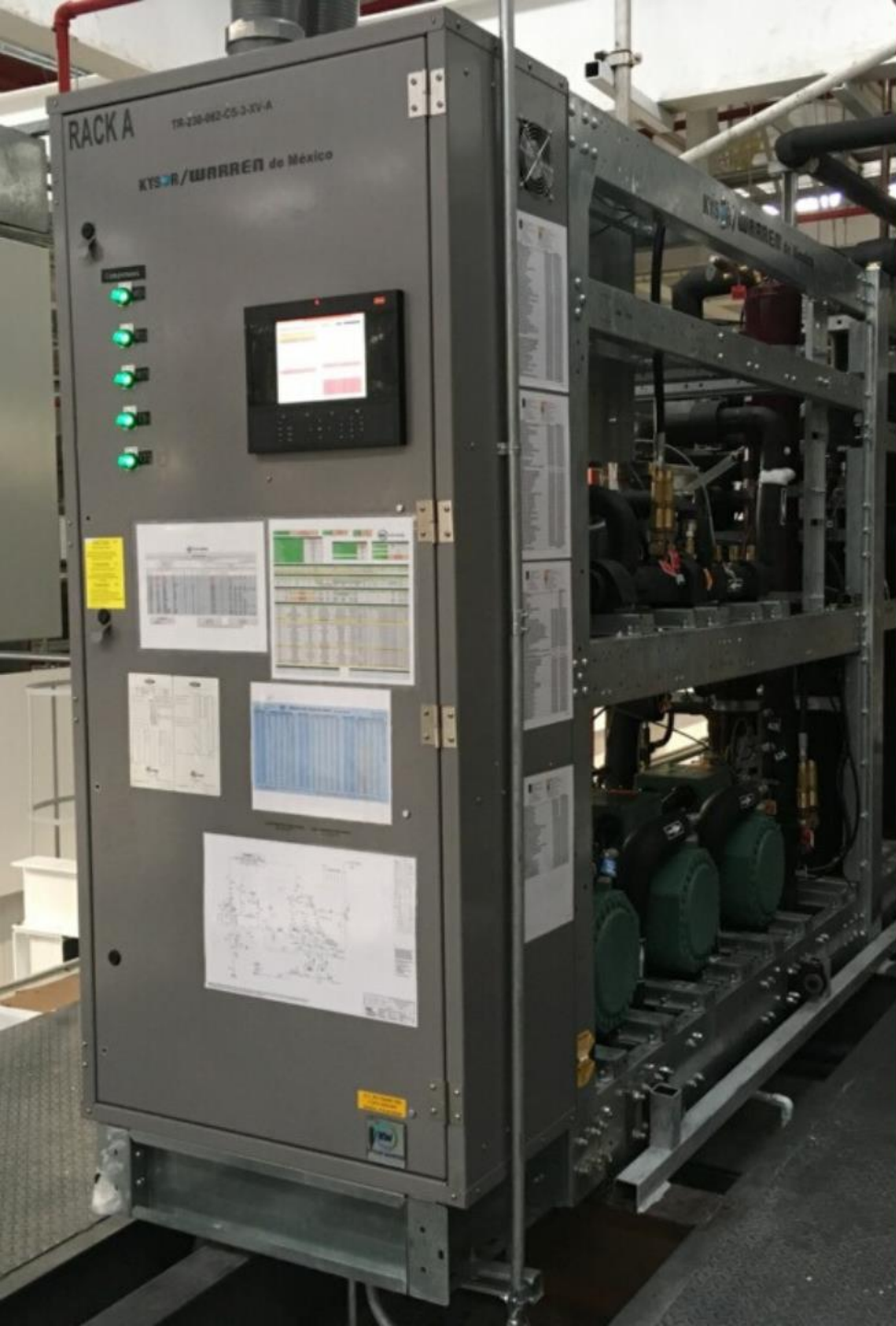
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NASRC National Training Summit

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3/30/2023

About Me

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



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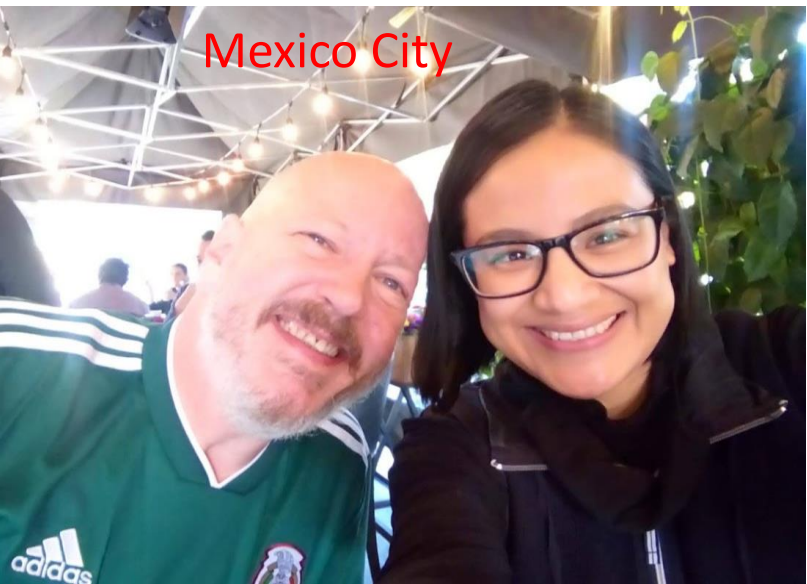
About Me



Ireland



St. Louis



Mexico City



San Luis Potosi

LEARNING OBJECTIVES

1. How did we get (back) to CO₂??
2. CO₂ 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



TYPES OF REFRIGERANTS

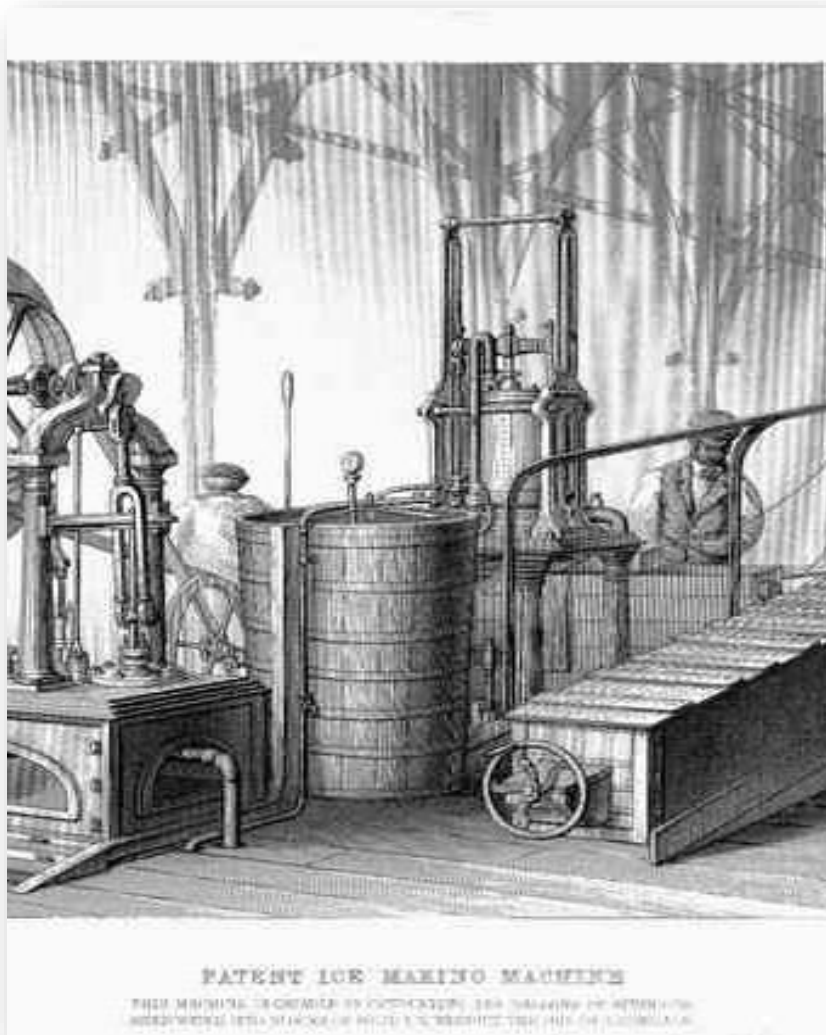


NATURAL, BUT WITH A BIT OF WORK...

- 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"



EARLY DAYS (LATE 1800's - 1929)



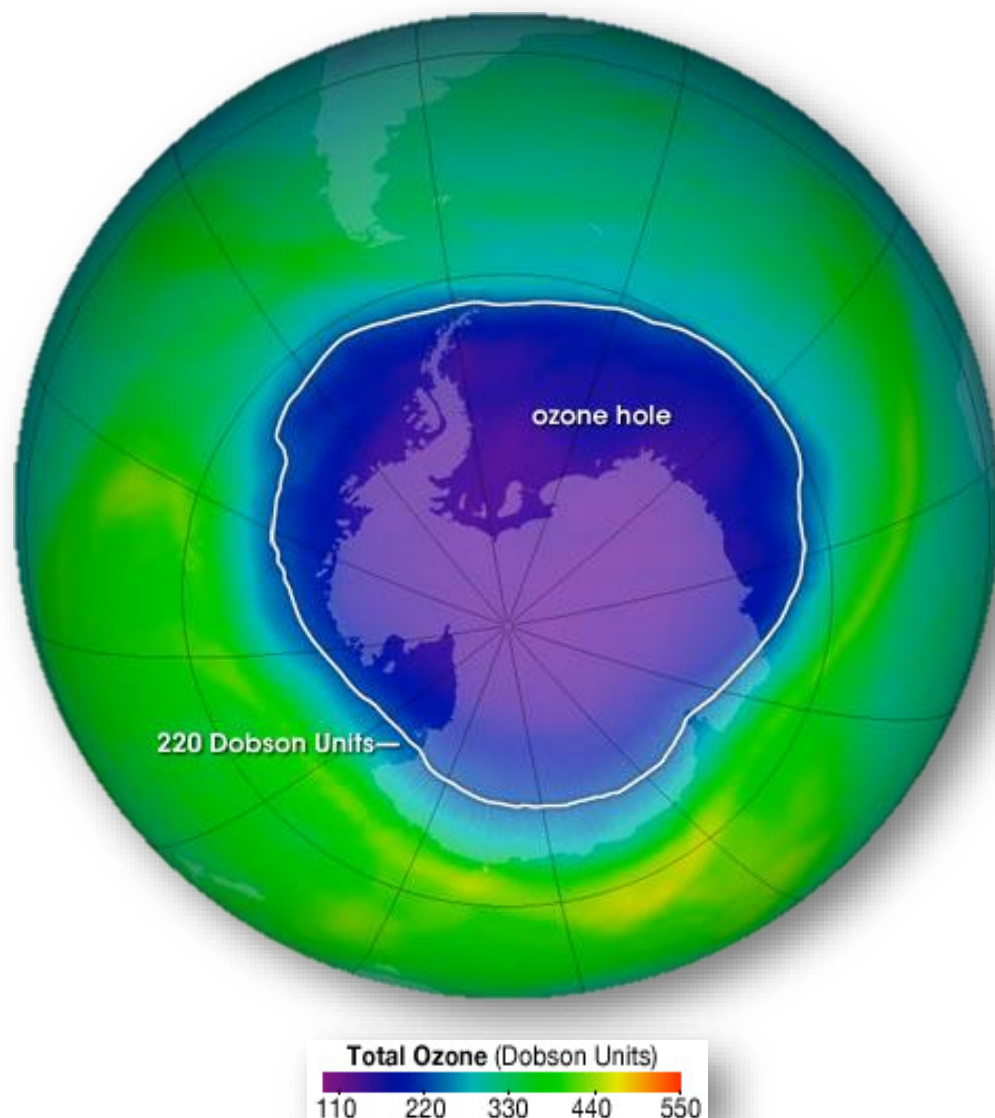
- Ammonia (NH_3)
- Methyl Chloride (CH_3Cl)
- Sulfur Dioxide (SO_2)
- Carbon Dioxide (CO_2)
- “Whatever Worked” era
- Availability and ability to work with the equipment of the time.
- Some are still used today (Ammonia, Propane, CO_2)
- Others fell out of favor due to high toxicity

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



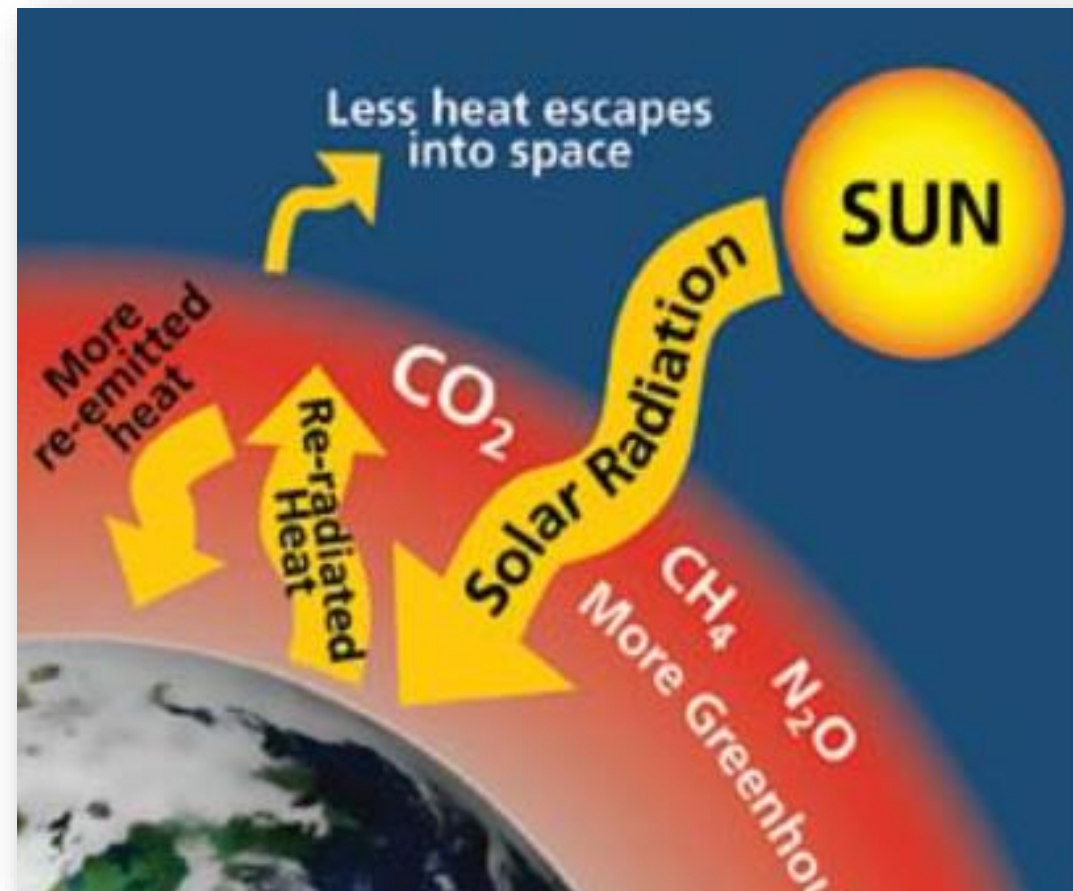
AGE OF SYNTHETICS (1930's-1990's)



- 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

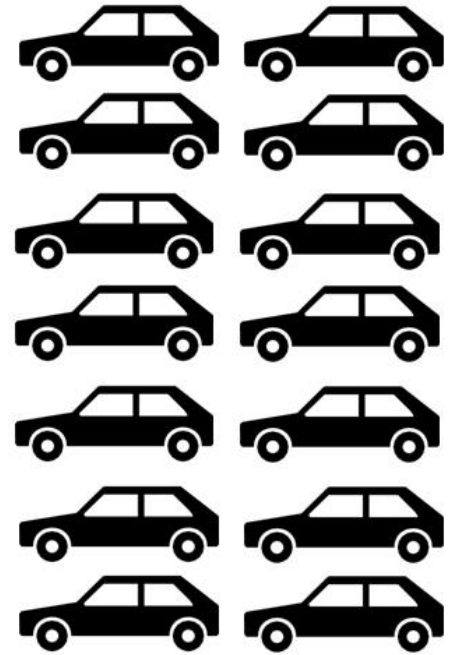
- R-12 = 10,600
- R-22 = 1,700
- R-448A = 1,170
- R-513A = 630
- R-744 = 1



=



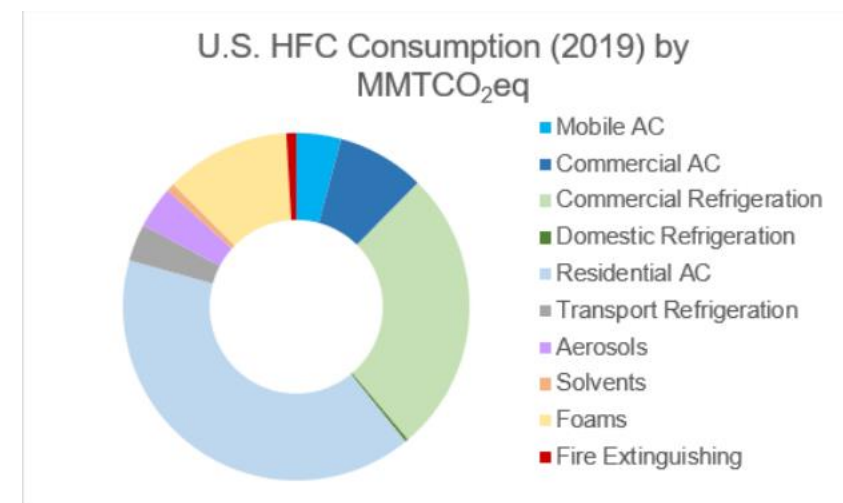
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two tanks R-22 = one tank R-404A = annual fuel for 14 cars

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



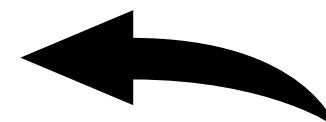
	GWP	
Retail food refrigeration – stand-alone units	150	January 1, 2025
Retail food refrigeration – refrigerated food processing and dispensing equipment	150	January 1, 2025
Retail food refrigeration – supermarket systems with refrigerant charge capacities of 200 pounds or greater	150	January 1, 2025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

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

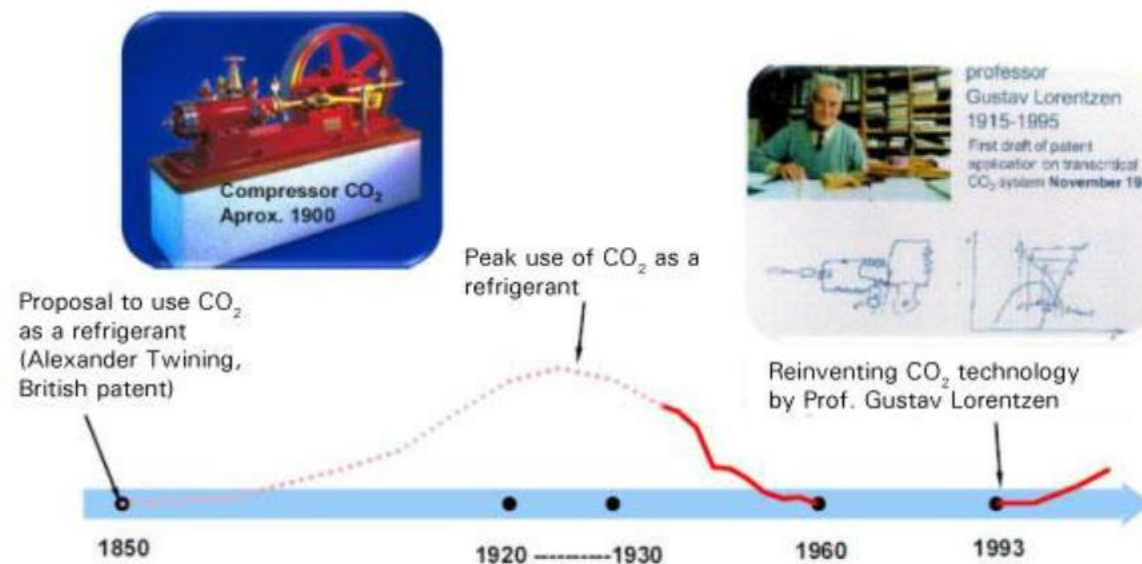
BACK TO THE NATURE...SORT OF



- 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

CO₂ 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 CO₂ 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 CO2 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 CO₂ Systems

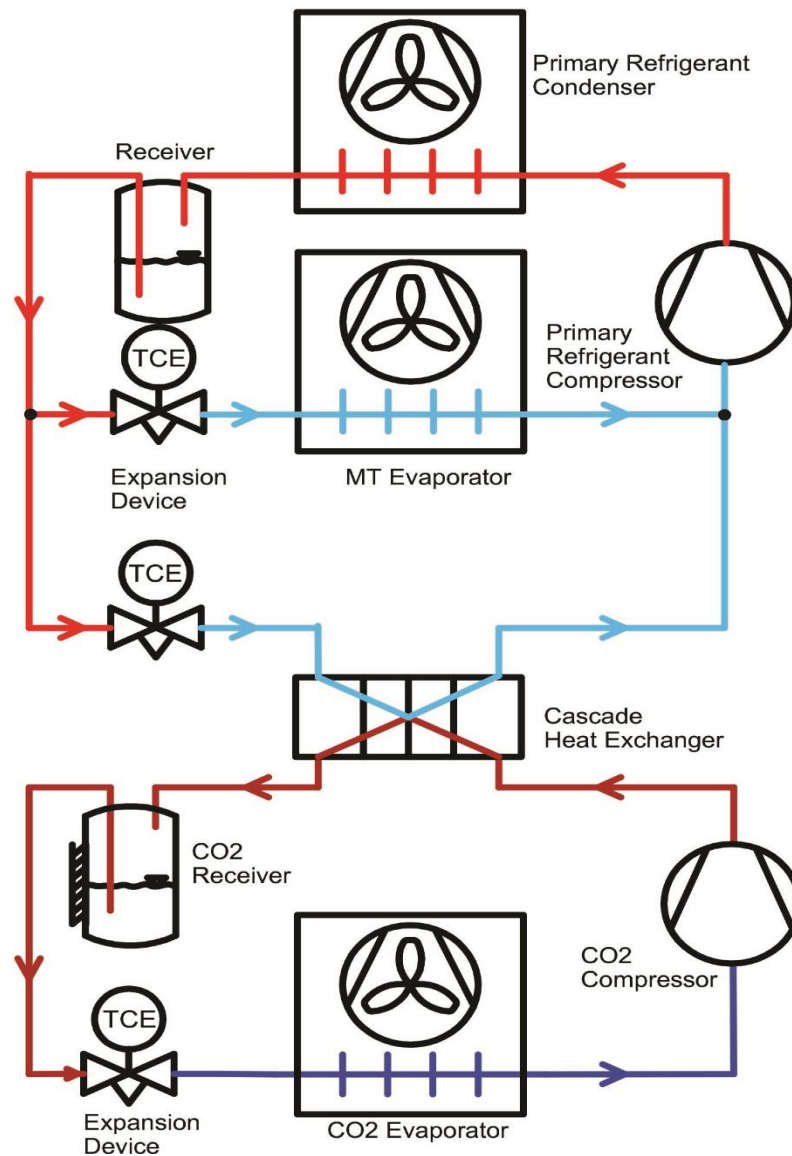
Cascade

- Uses CO₂ 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

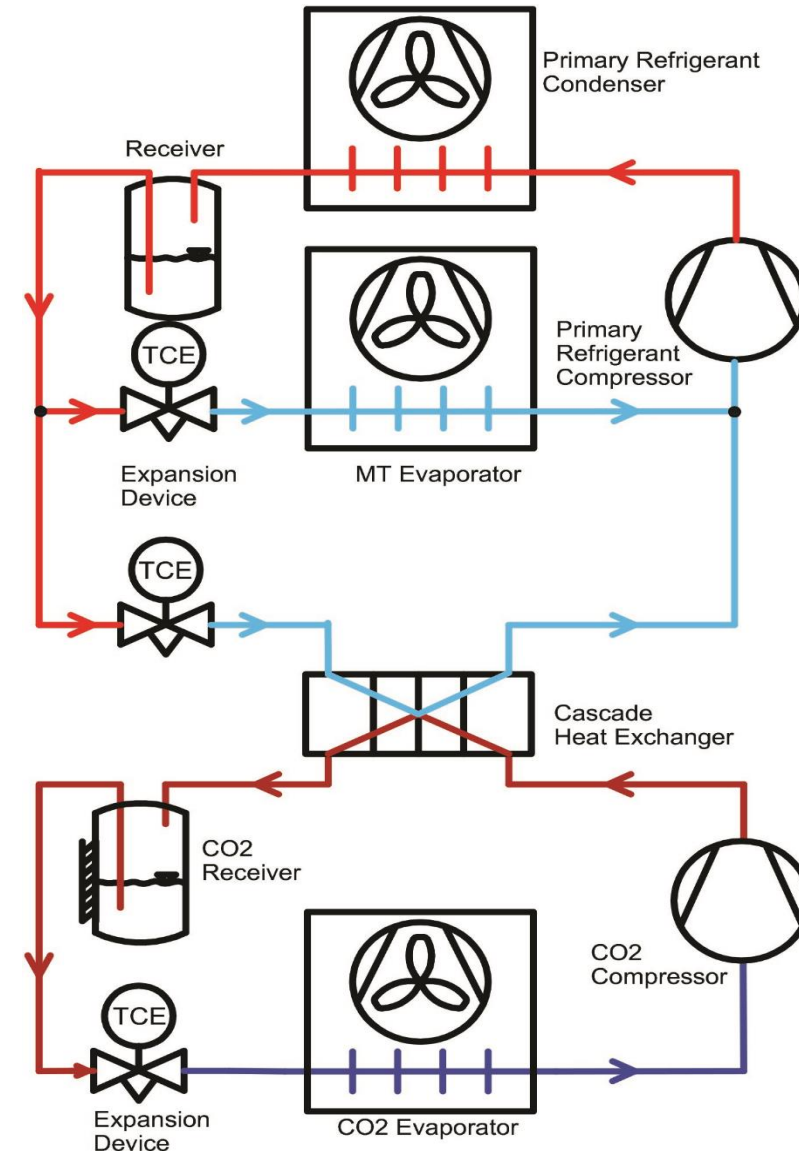
- 100% CO₂ used for both medium and low temperature applications
- **Initially** limited to colder areas for efficiency reasons

Cascade Systems



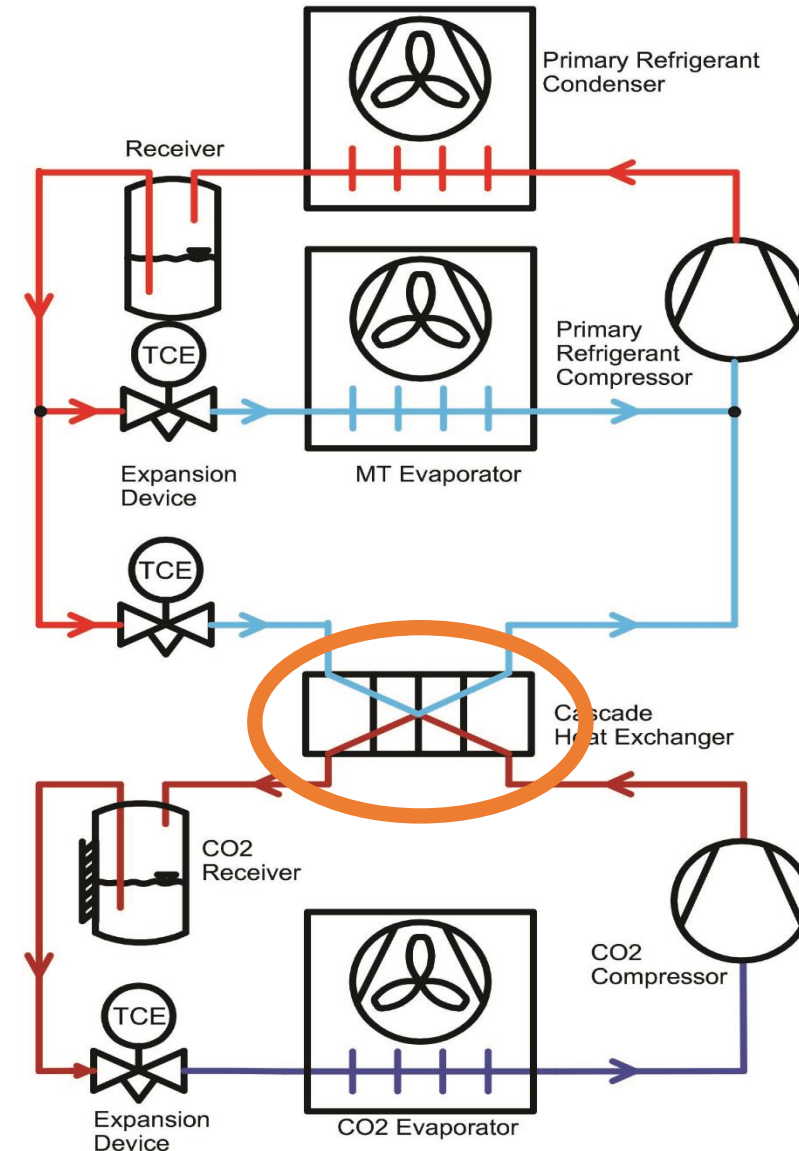
CO₂ Cascade Systems

- Uses 2 types of refrigerants
- CO₂ will handle the low temperature load and is known as the secondary refrigerant
- The primary refrigerant can be whatever the customer wants (NH₃, HFC's, even glycol) will cool the medium temperature load and condense the CO₂



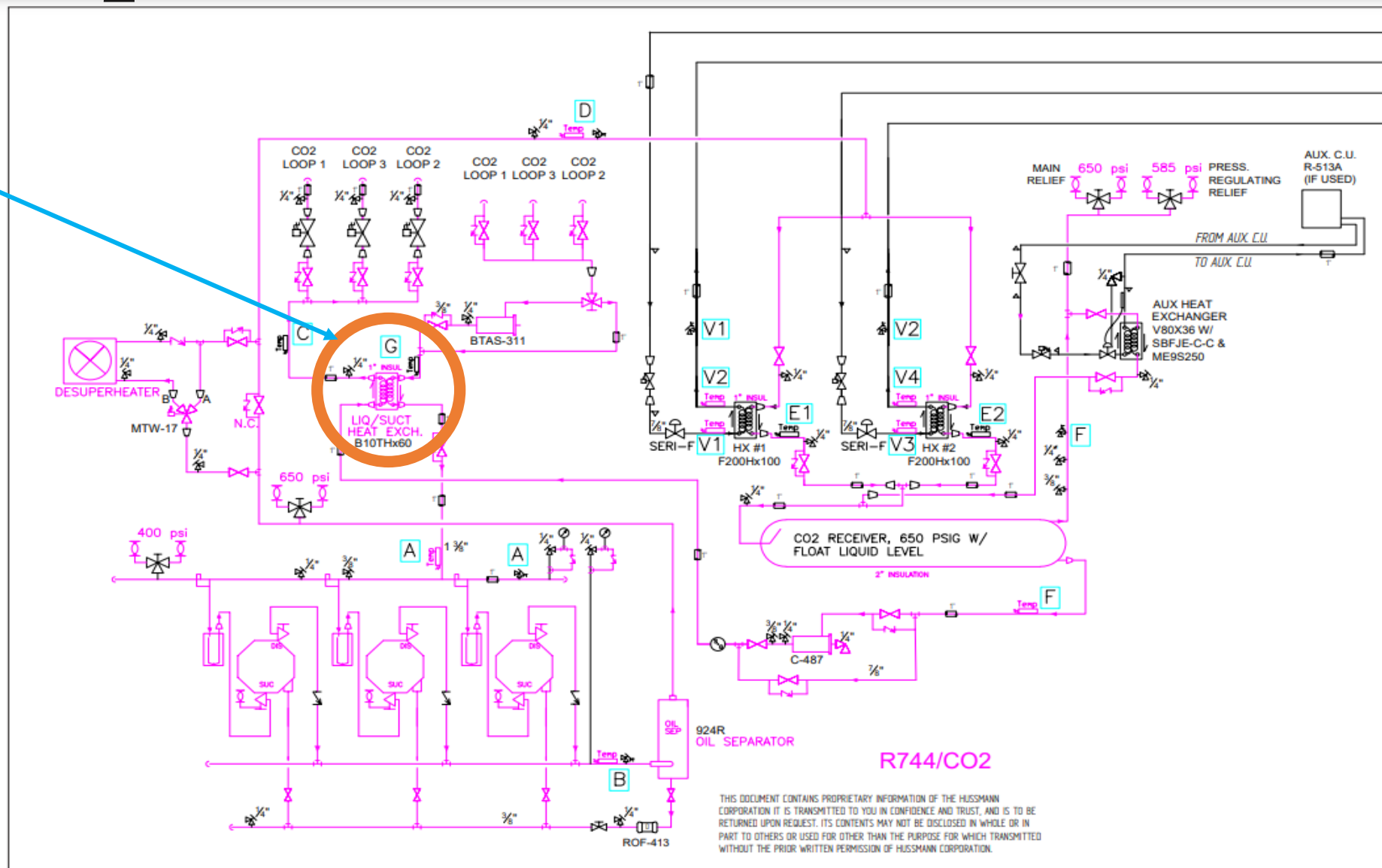
CO₂ Cascade Systems

- 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



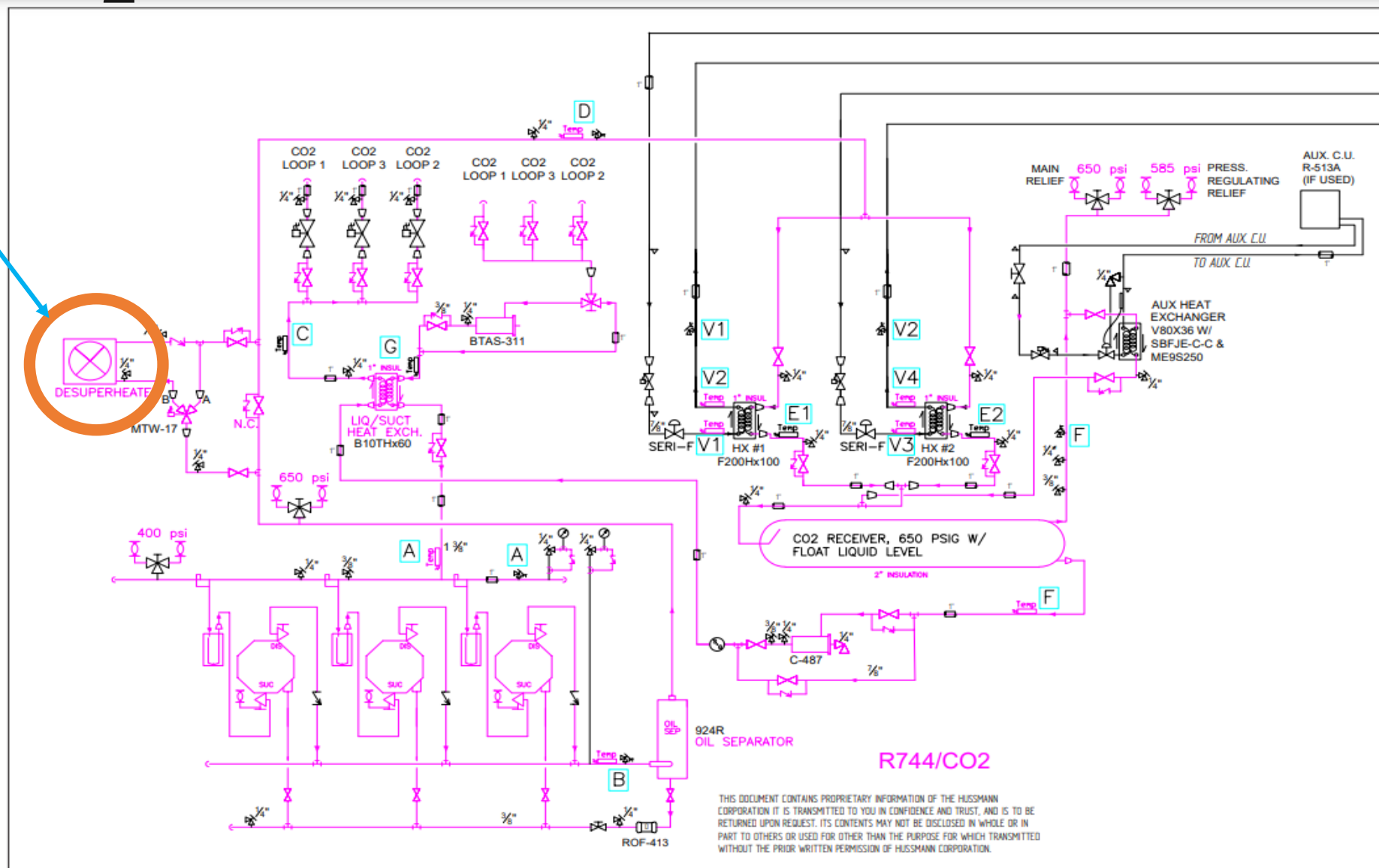
CO₂ Cascade Systems

- Liquid/Suction Heat Exchanger
- Adds subcooling to liquid CO₂
- Adds superheat to the CO₂ compressor suction



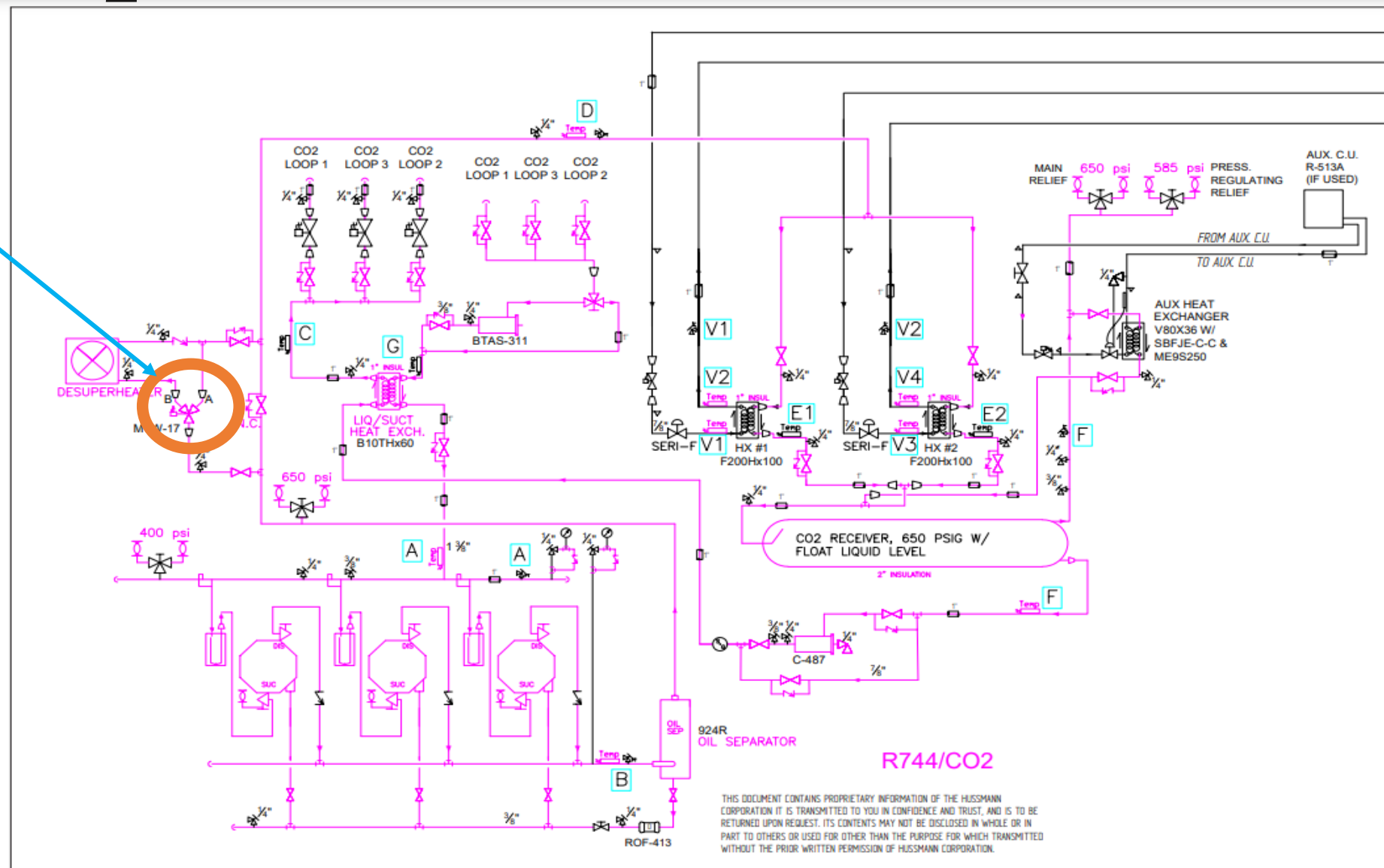
CO₂ Cascade Systems

- The Desuperheater removes excess heat from the CO₂ compressor discharge
- Keeping the proper CO₂ temperature is important to maintaining cascade function



CO₂ Cascade Systems

- Modulating 3 Way Valve
- Changes the amount of CO₂ going to the desuperheater to maintain the proper temperature going to the cascades
- Cascade inlet set point is around 105-115F

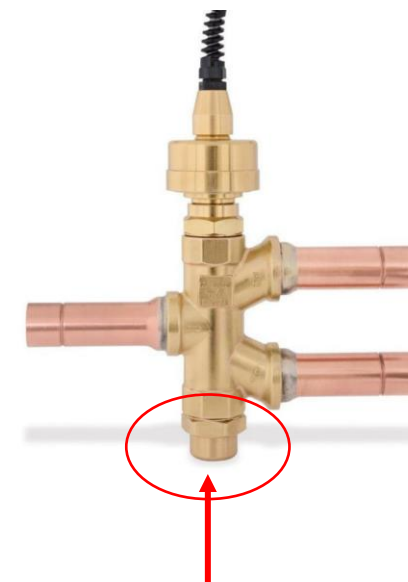


CO₂ Cascade Systems

- Modulating 3 Way Valve
- Sends gas to either the desuperheater or a bypass
- If improperly piped or programmed, it can cause CO₂ condensation before the cascade
- This can cause system performance issues



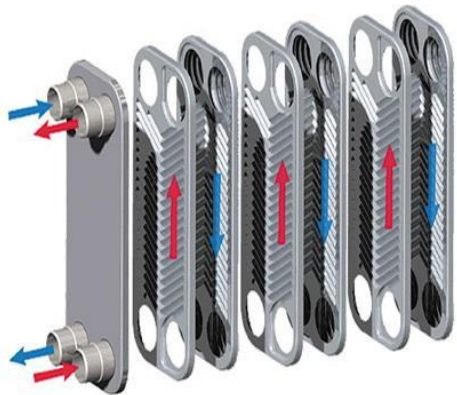
'B' PORT is going to the Desuperheater
'A' PORT is the bypass



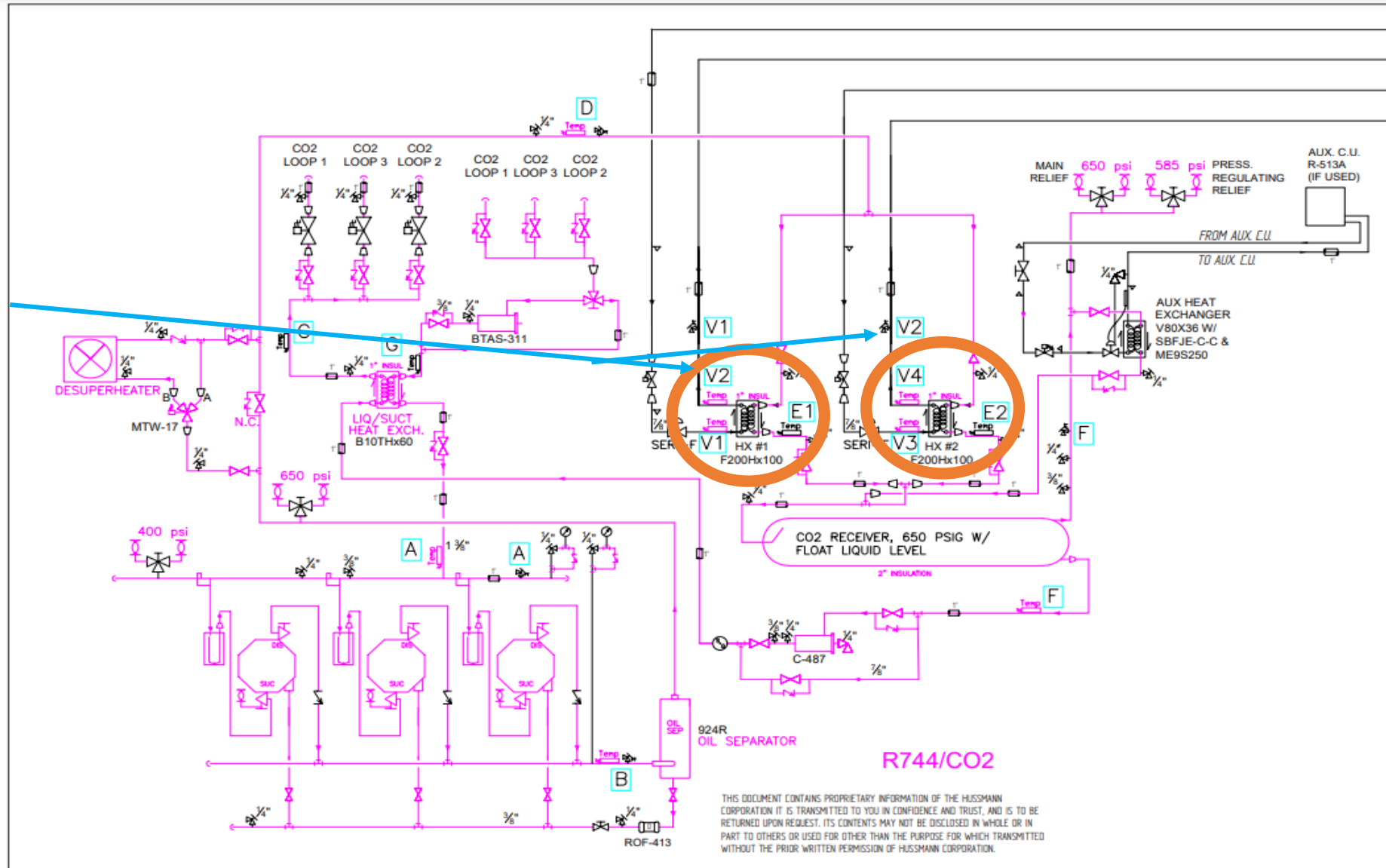
Servicable type

CO₂ Cascade Systems

- The Cascades
- This is where the CO₂ is condensed by the primary synthetic refrigerant
- Standard plate heat exchanger

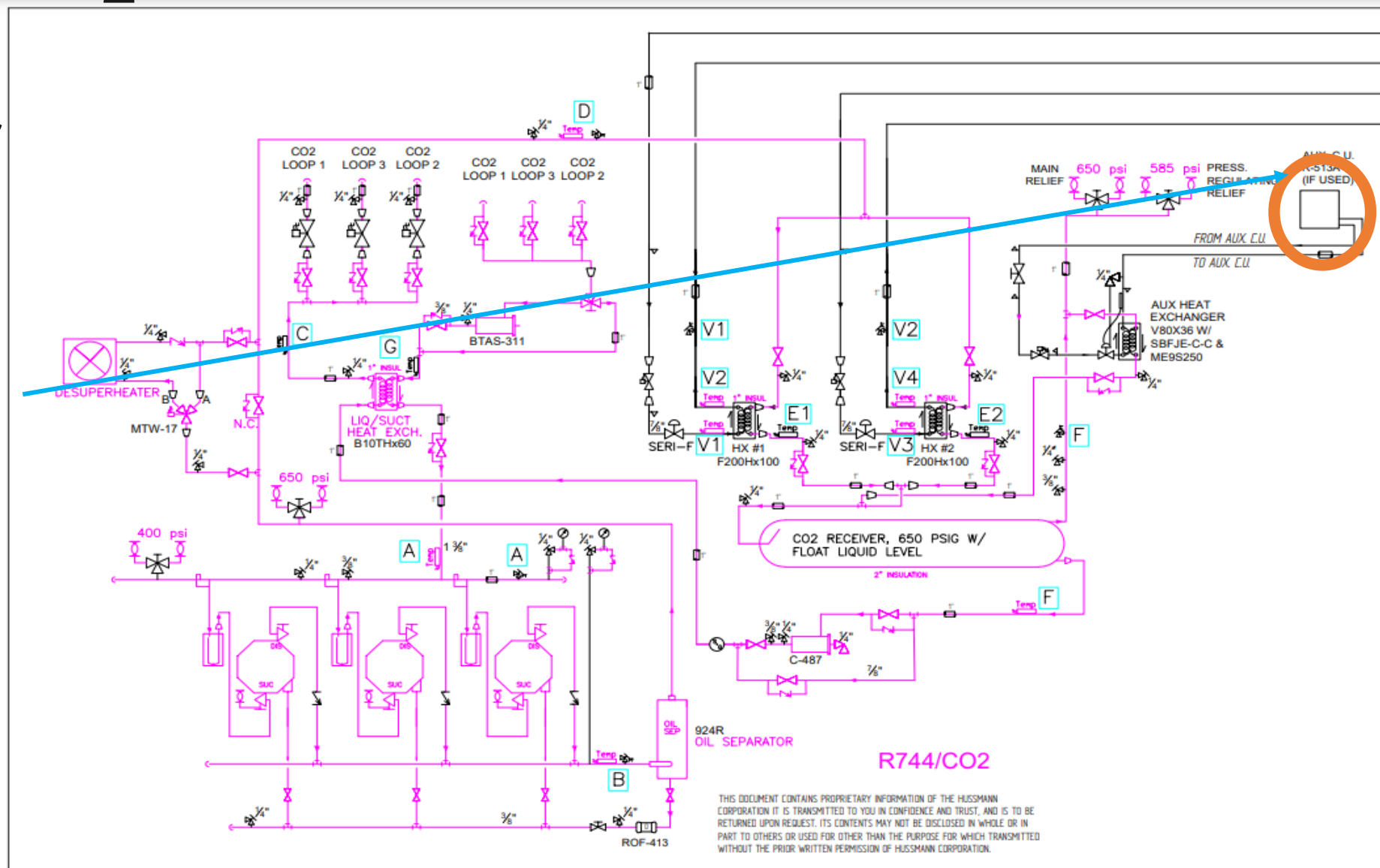


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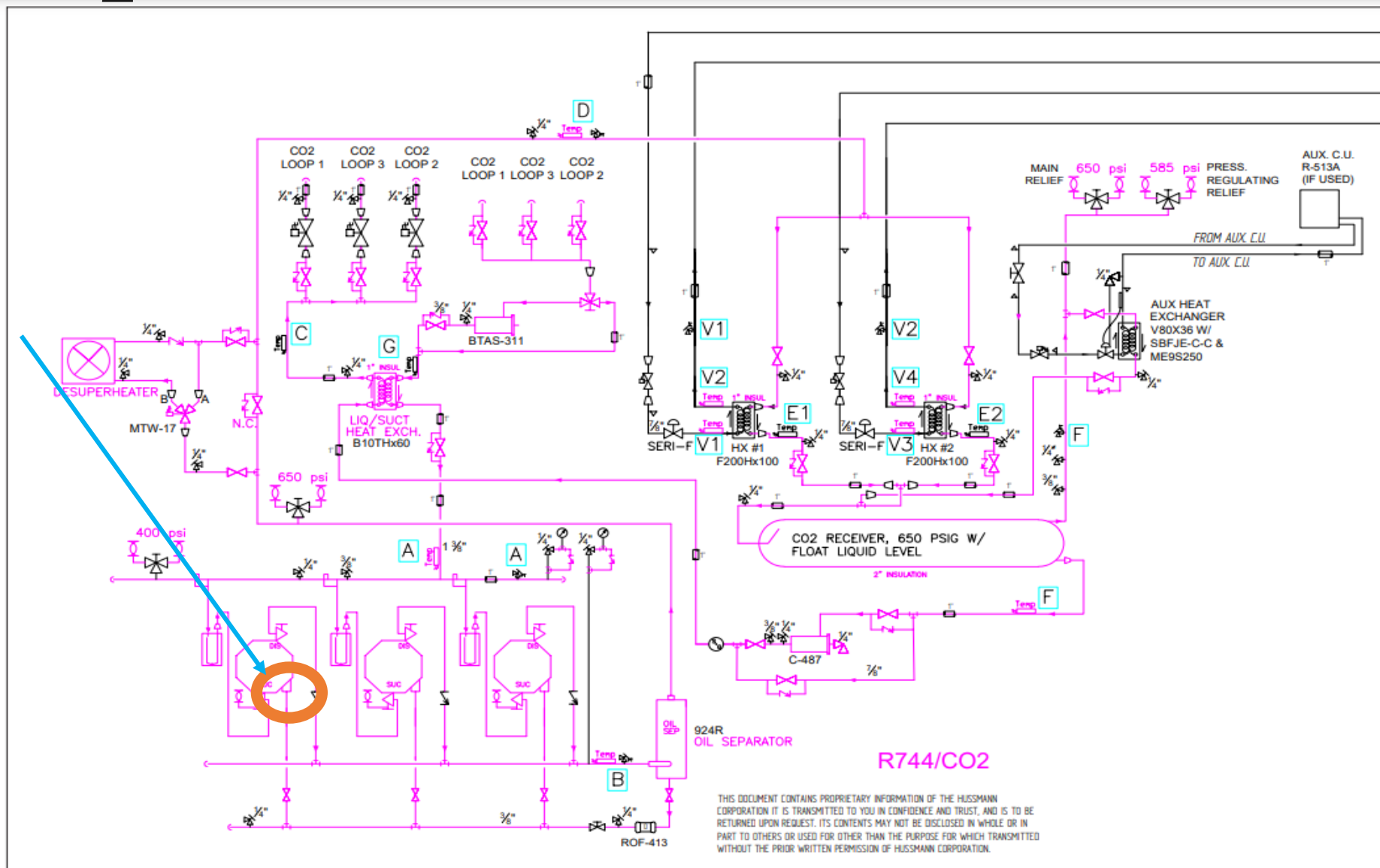
CO₂ Cascade Systems

- Auxiliary Condenser
- Hooked to EPS
- In the event of a power failure, it will circulate and cool CO₂ from the receiver
- This prevents relief valves lifting and lost charge



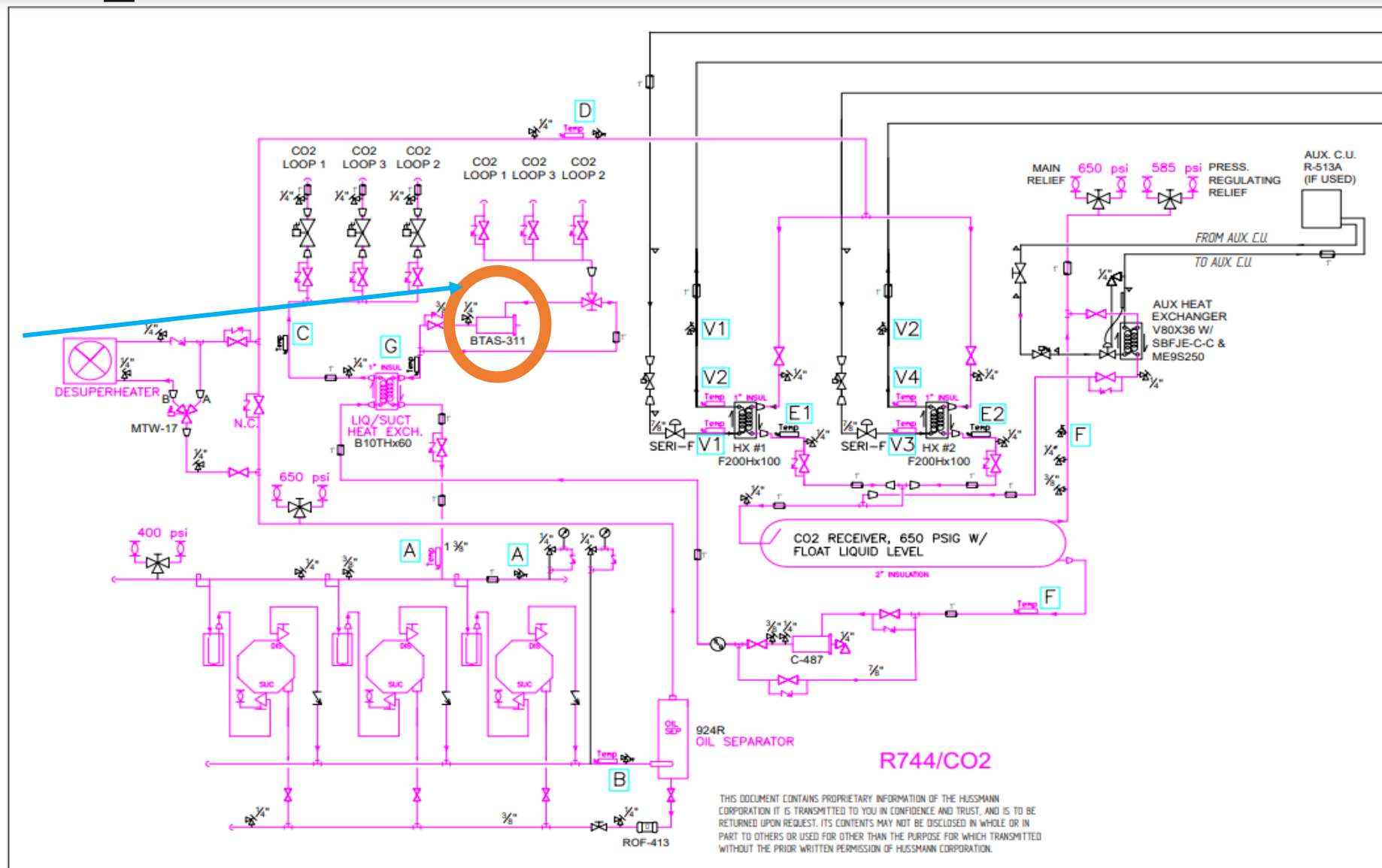
CO₂ Cascade Systems

- CO₂ compressors use the Emerson OMC to maintain oil level
- The HFC compressors use Sporlan



CO₂ Cascade Systems

- Suction Filters
- It is recommended to leave the filter in after start up on CO₂ systems
- They should be changed during during PM



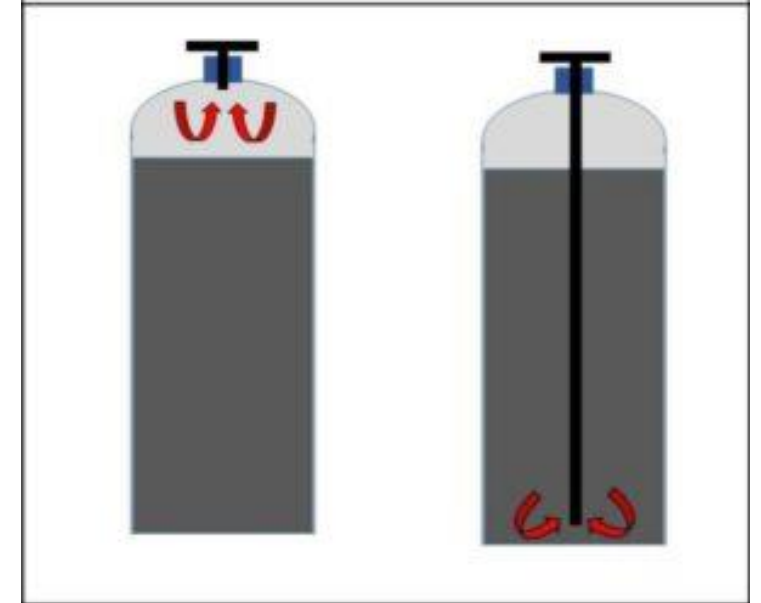
A Word About Charging CO₂

CO₂ Vapor Cylinders

- CO₂ 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 CO₂ cylinder ensure that it is the correct type and grade before using.

CO₂ Liquid Cylinders (w/dip tube)

- CO₂ 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**

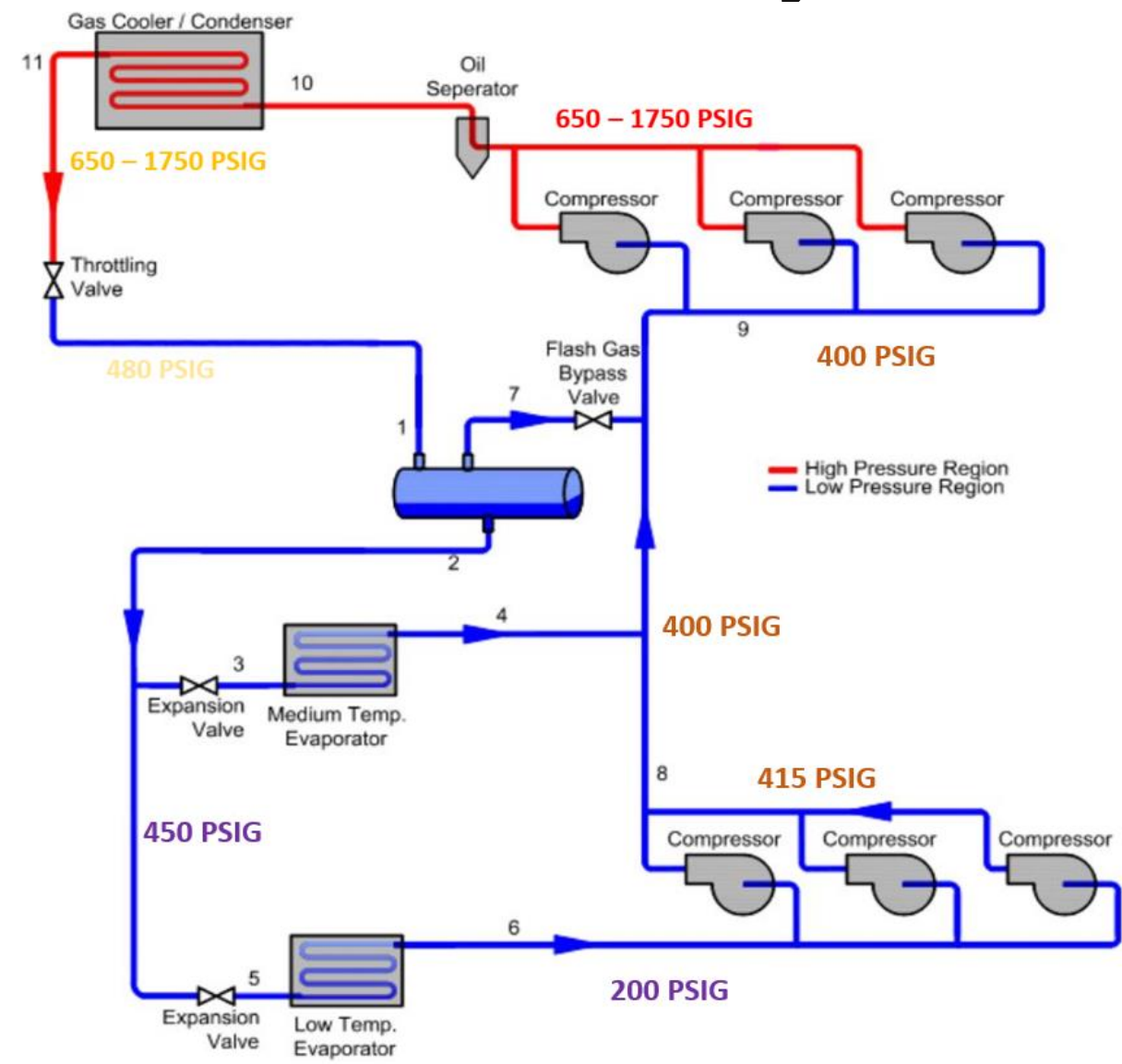


A Word About Charging CO₂

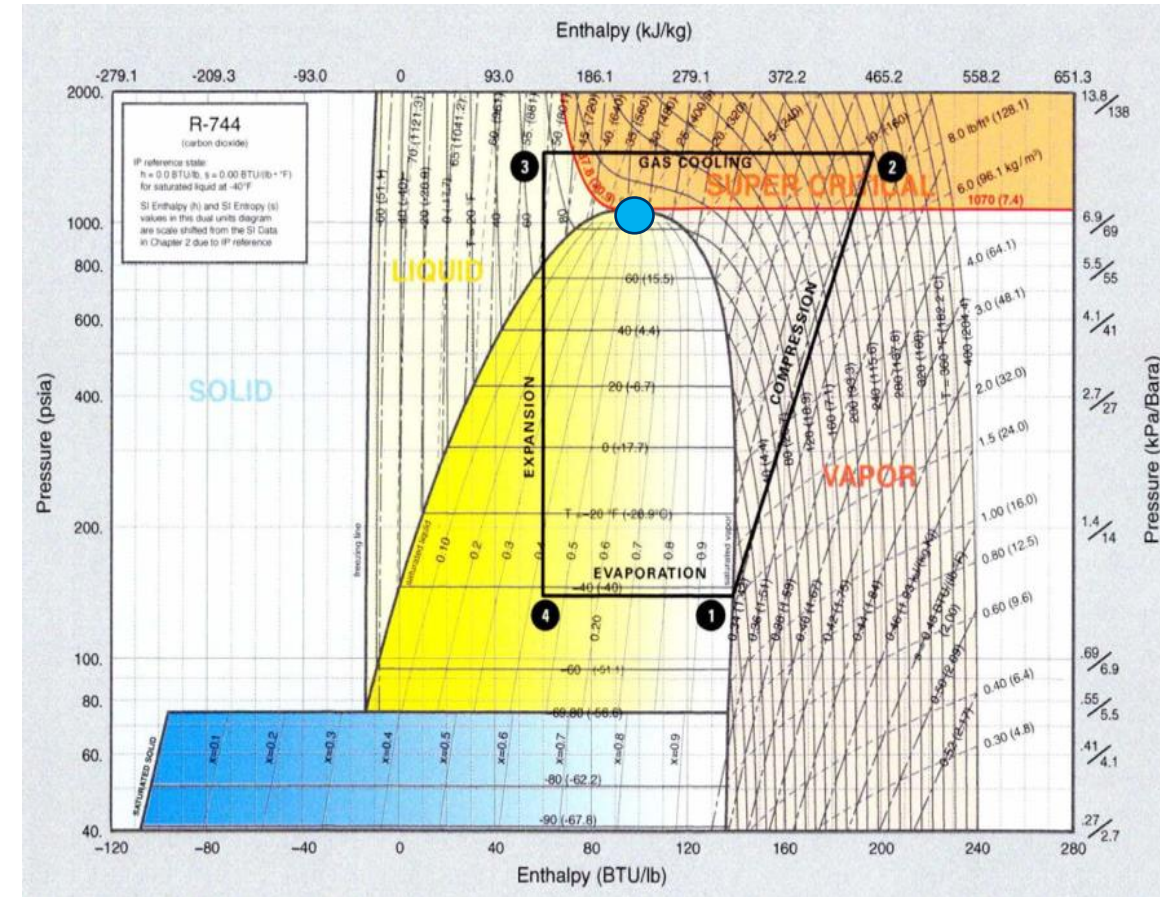


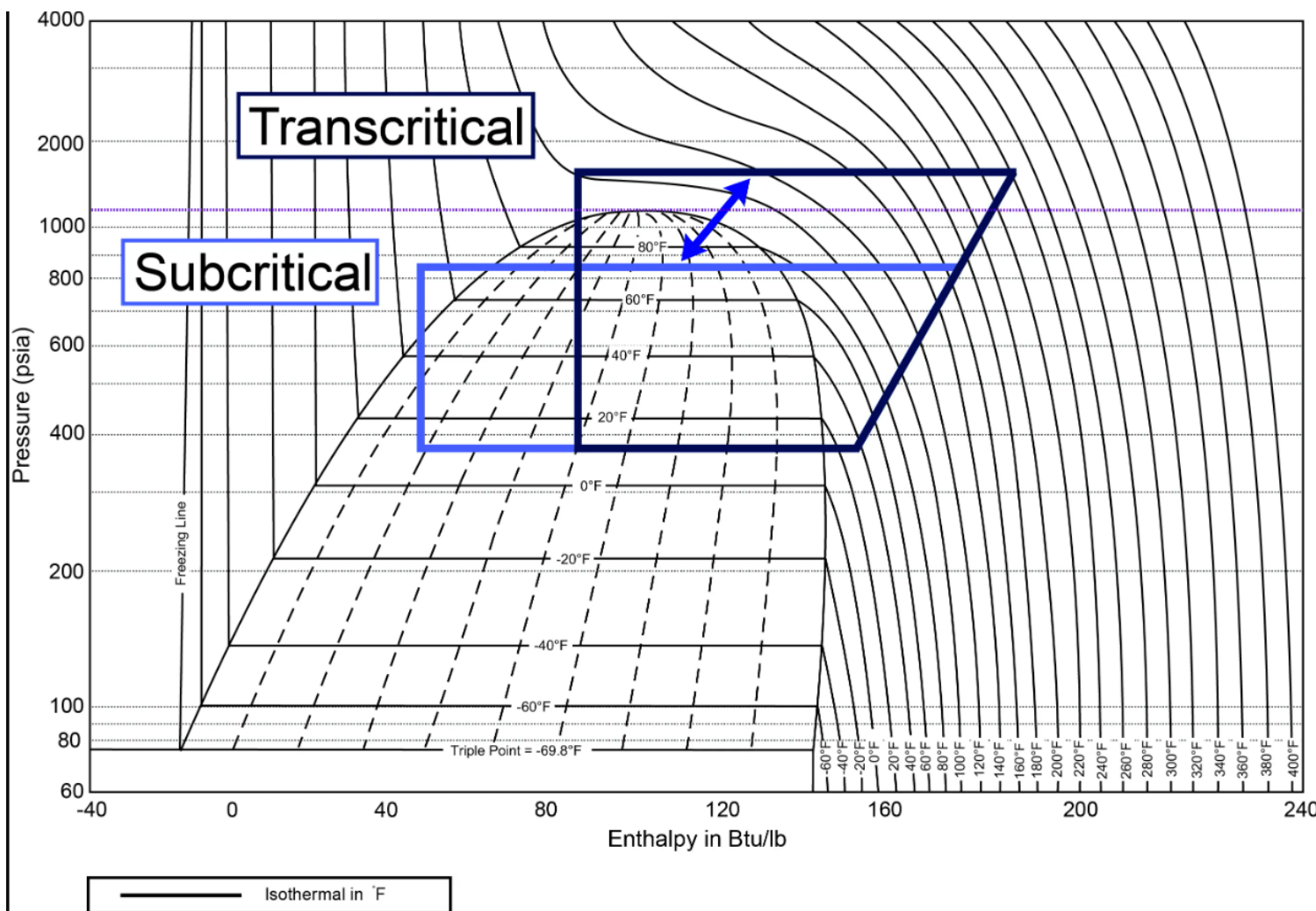
Phase change using only pressure change

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% CO₂ systems and other types (cascade or direct expansion)

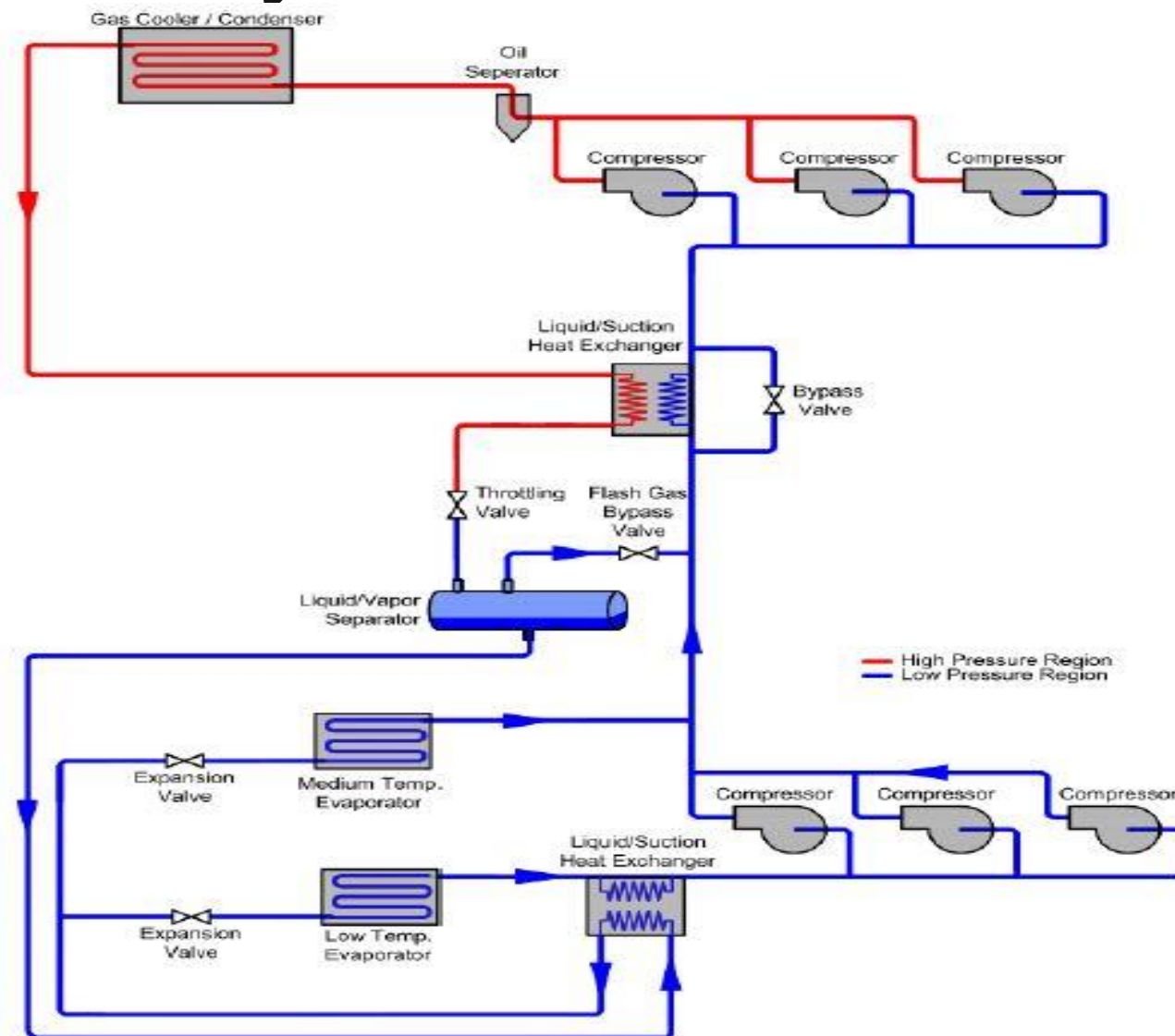




- In Sub-Critical operation, the condenser does just that..condenses the refrigerant by simply removing heat.
- In Trans-Critical operation (ambient temperature above 88F) The CO₂ can't condense just by the removal of heat, so the gas is cooled only.

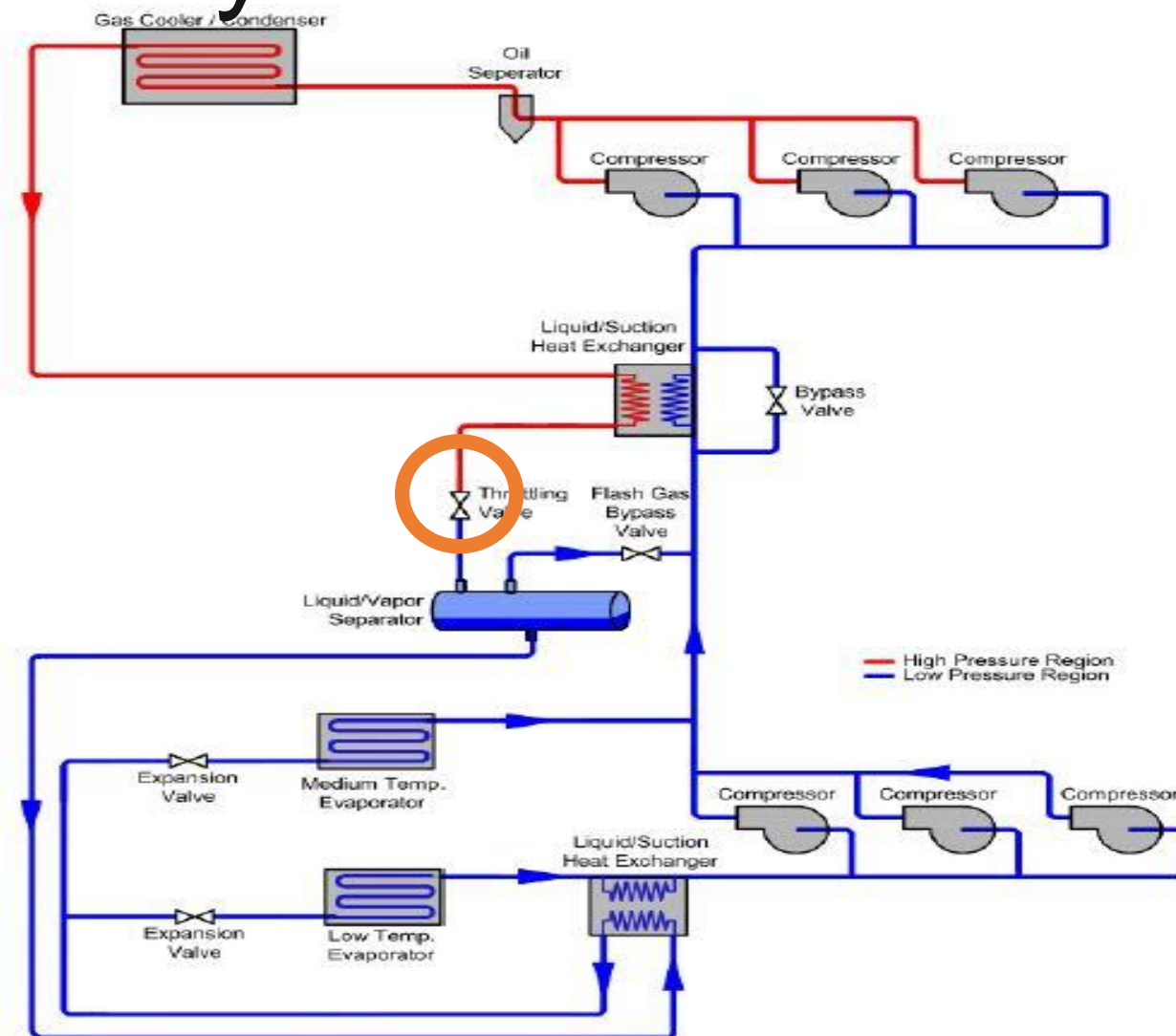
Transcritical Systems

- 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



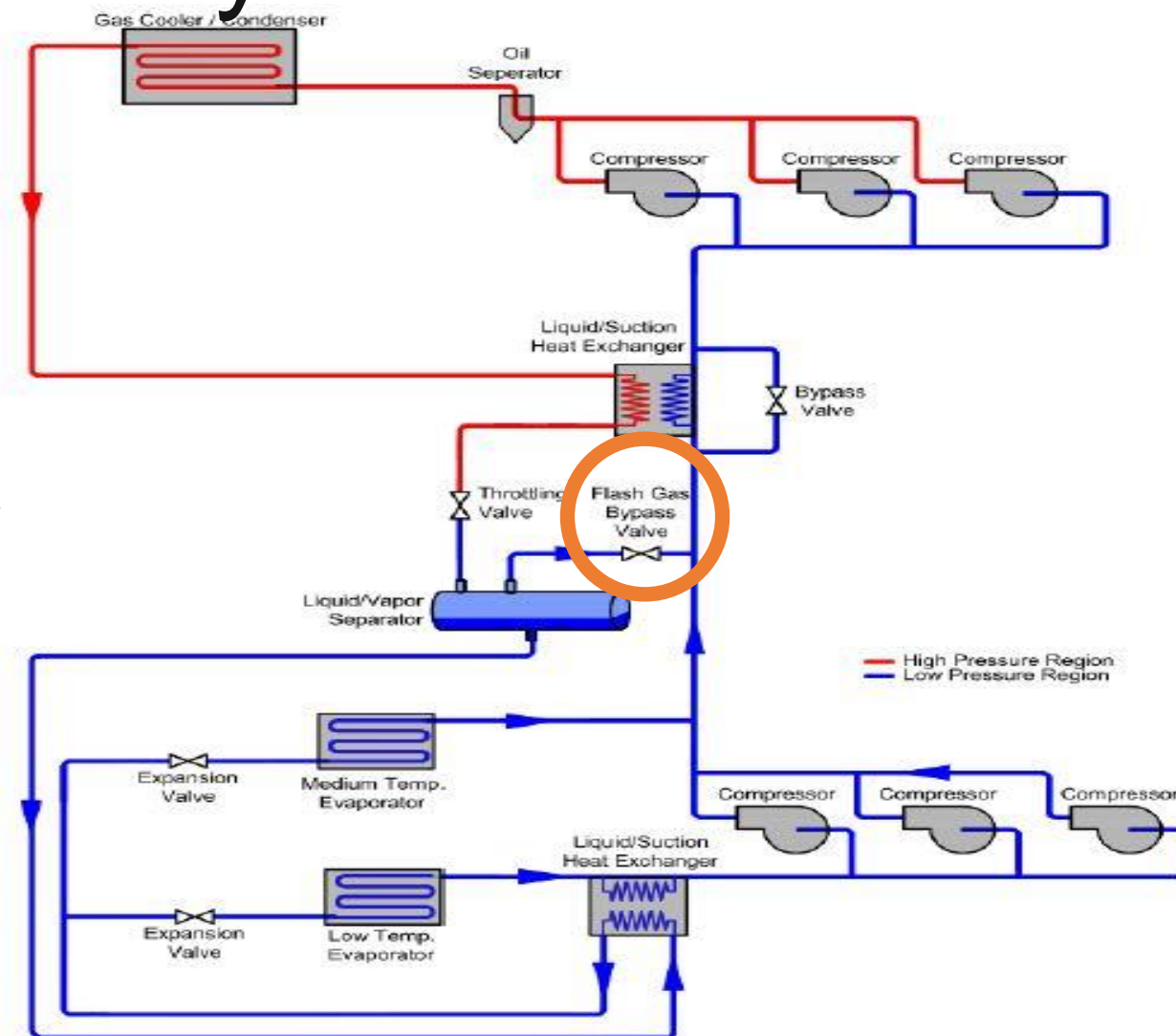
Transcritical Systems

- 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.



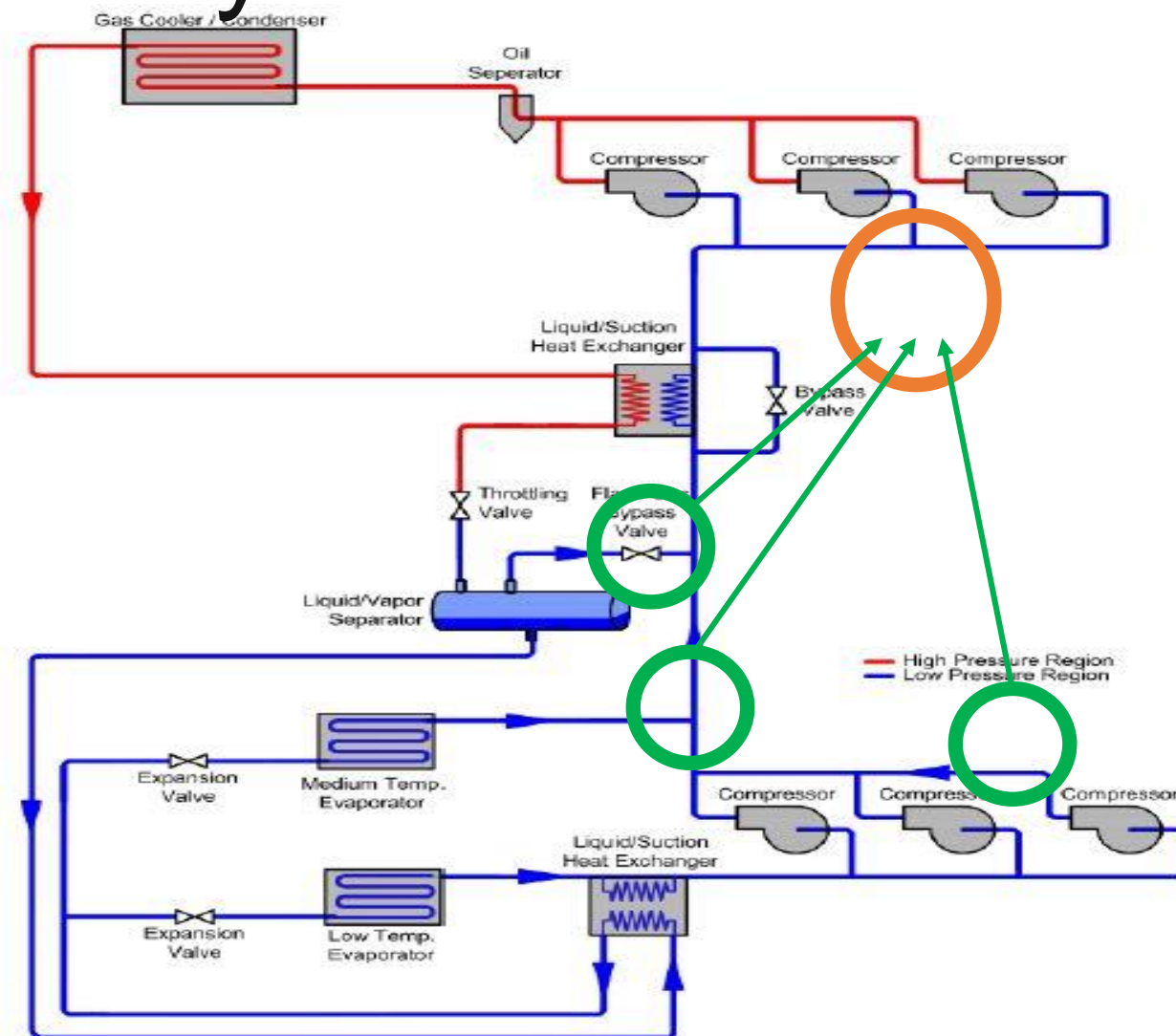
Transcritical Systems

- 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



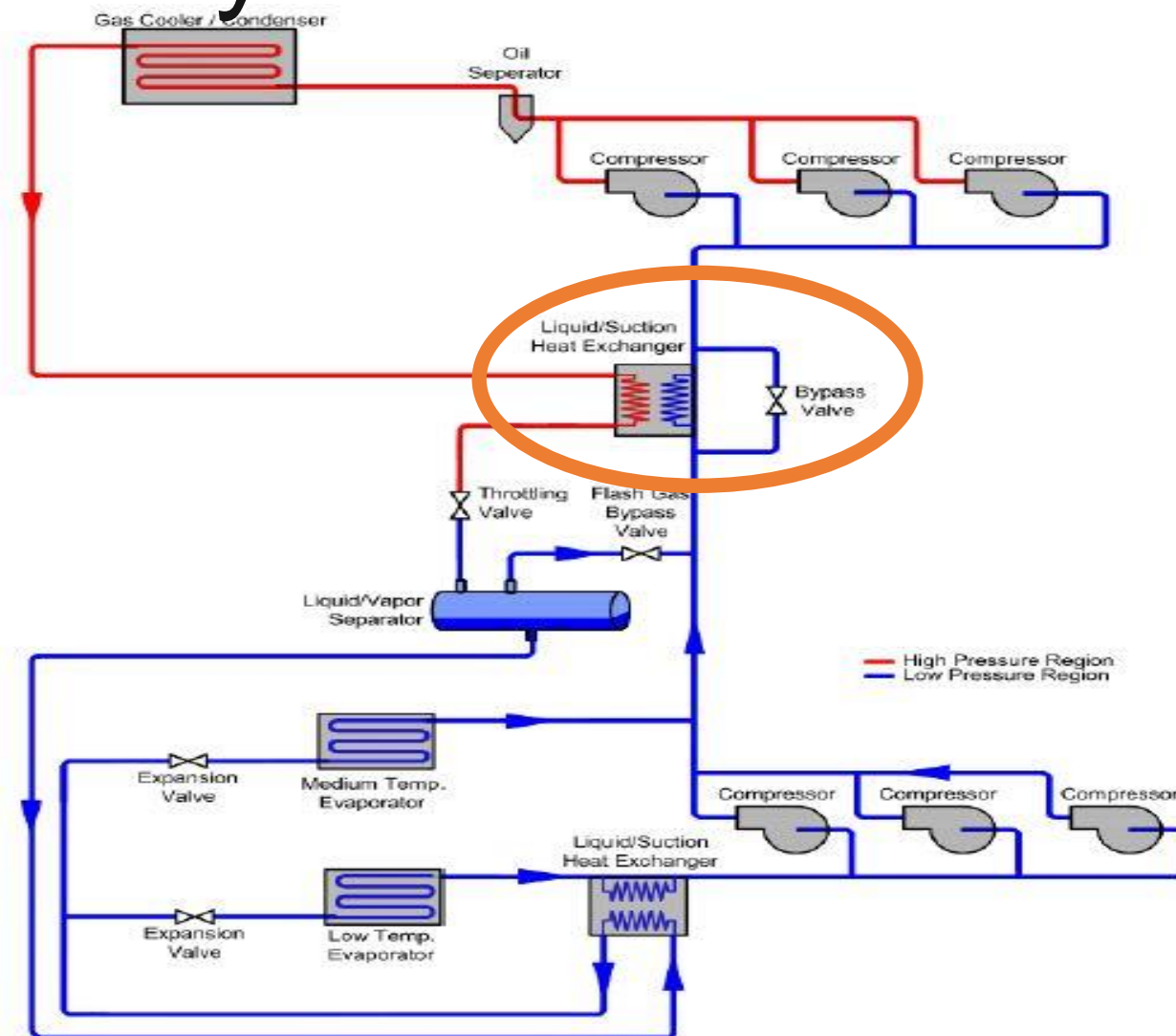
Transcritical Systems

- 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 CO₂ systems



Transcritical Systems

- Superheat control is **very** important on CO₂ systems
- If SH is too low, the system will begin pulling oil because of CO₂'s chemical properties
- If SH is too high, the oil will degrade resulting in poor lubrication and compressor wear



Trans-Critical System Operation

◆ Liquid/Vapor mix

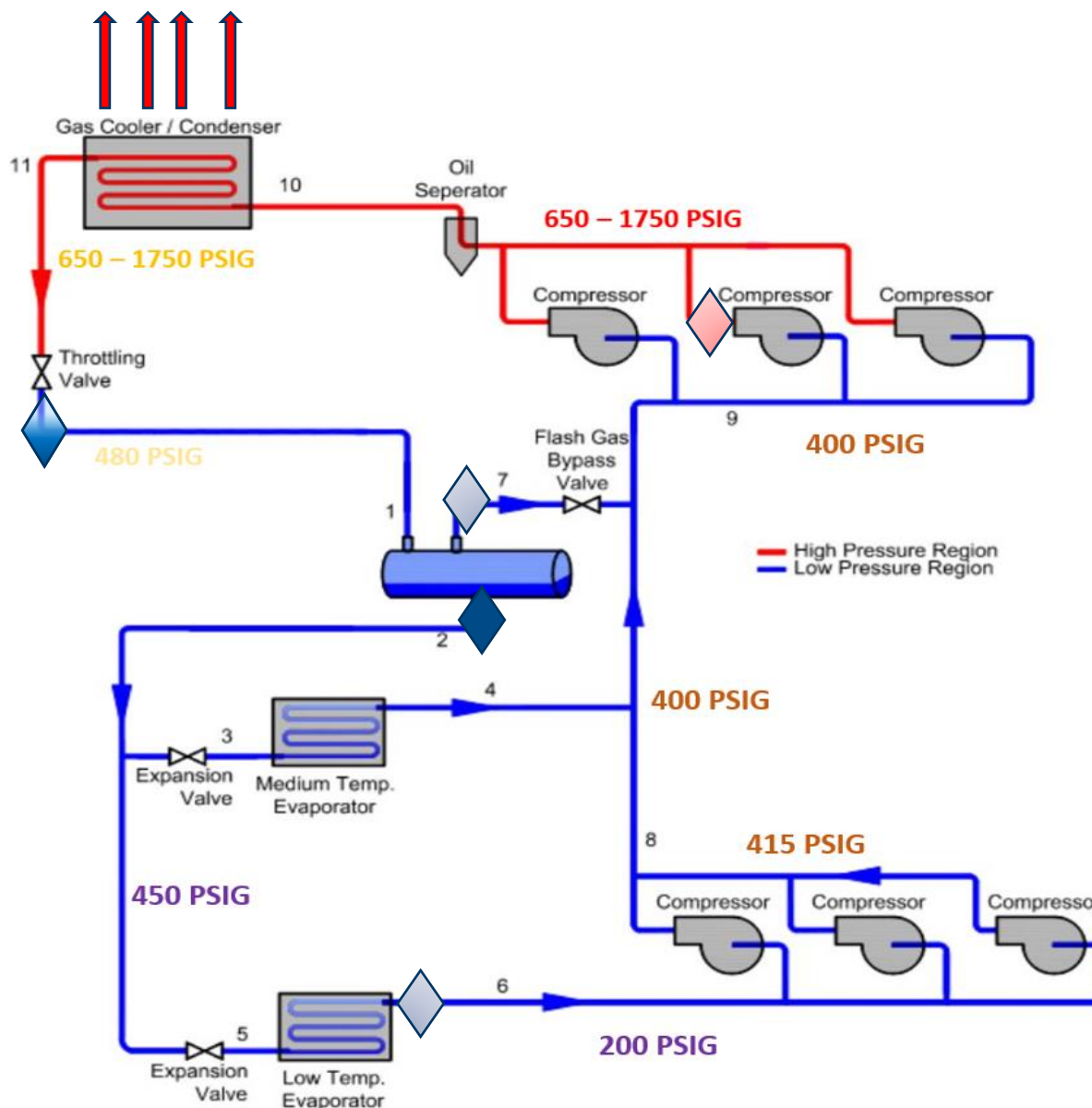
◆ Liquid

◆ Low Pressure vapor

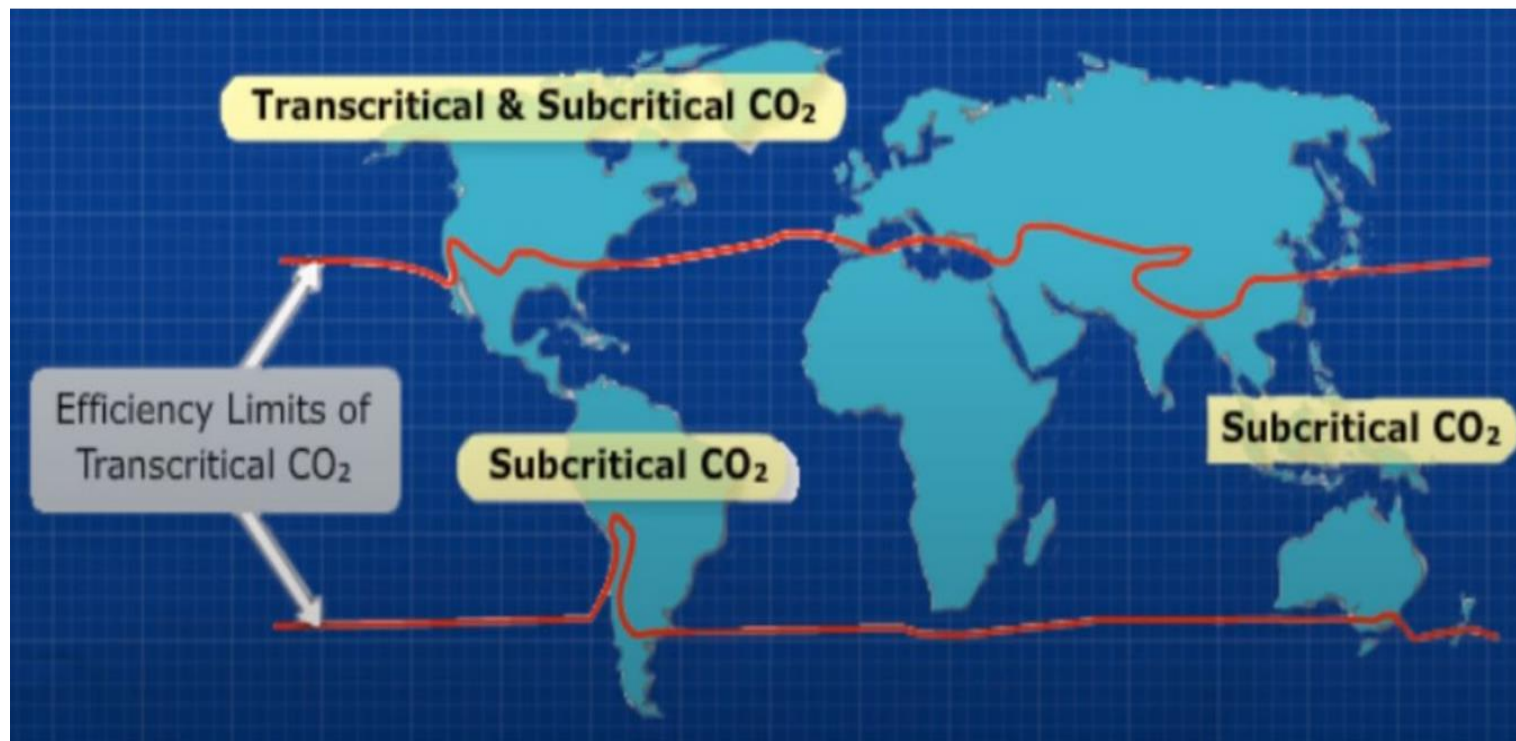
◆ High Pressure Vapor

↑ Heat rejected to atmosphere

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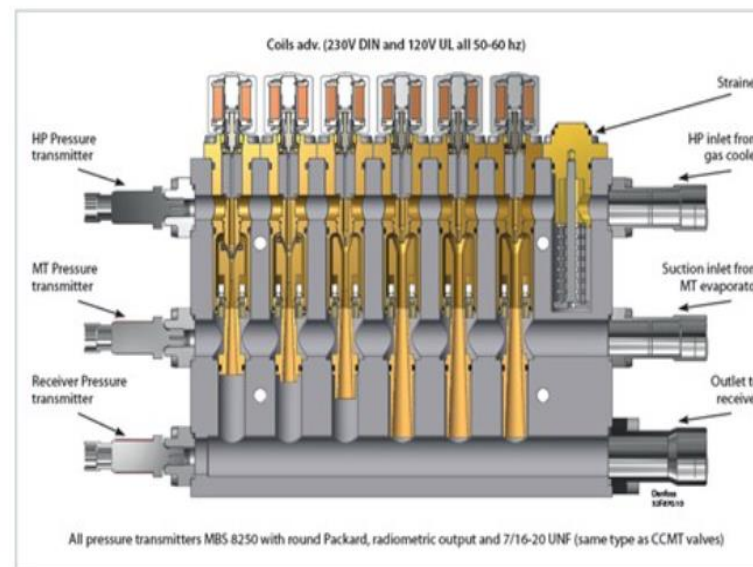
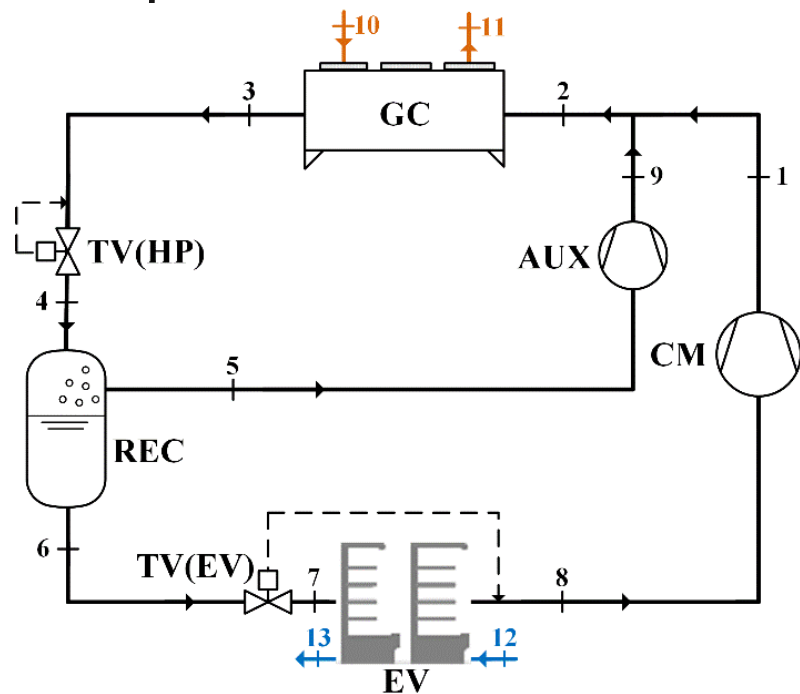
Improving Efficiency



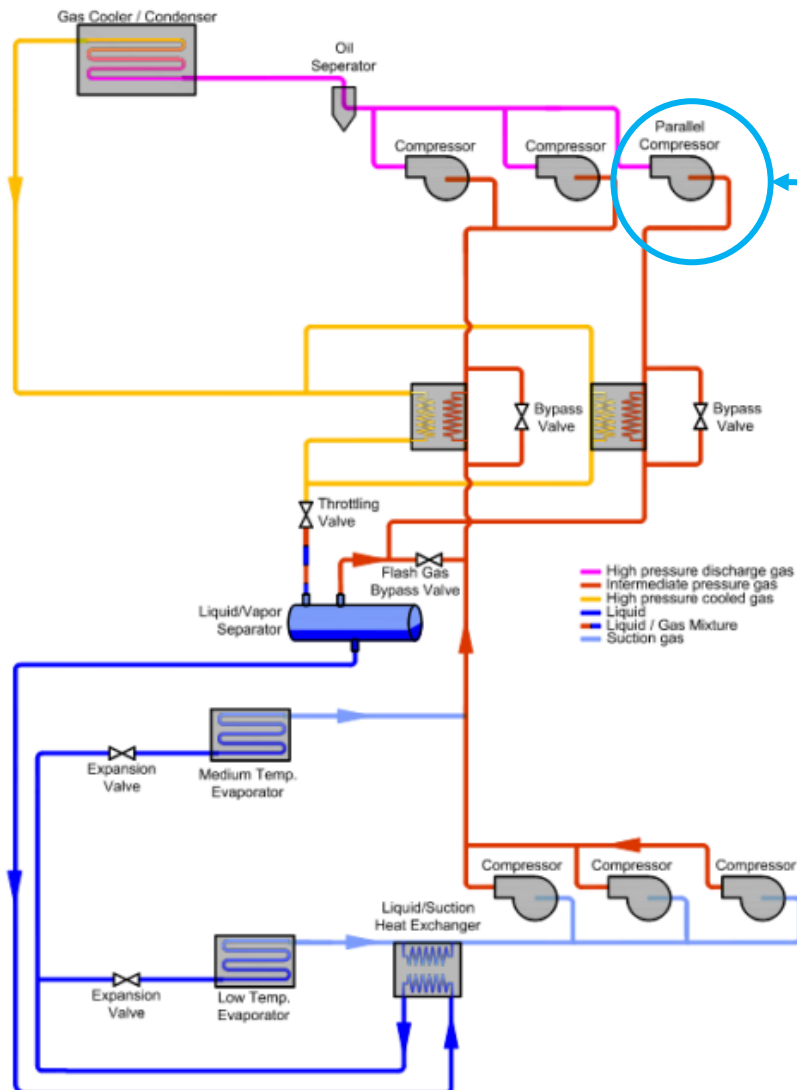
Traditionally, Transcritical systems in hotter climates paid a significantly high energy penalty which made them financially unfeasible. BUT THAT WAS THEN.....

Improving Efficiency

- Parallel Compression
- Adiabatic Gas Coolers
- Multi-Ejectors

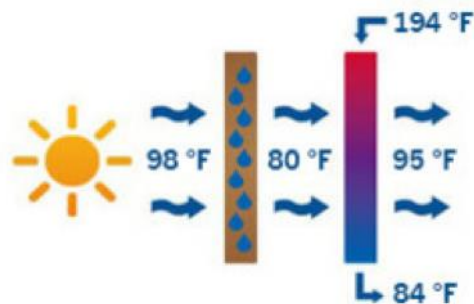
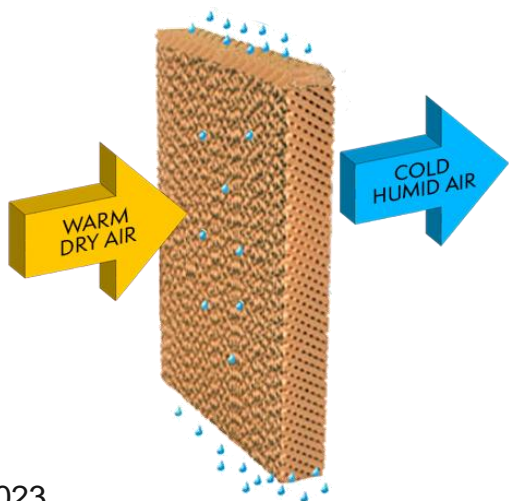
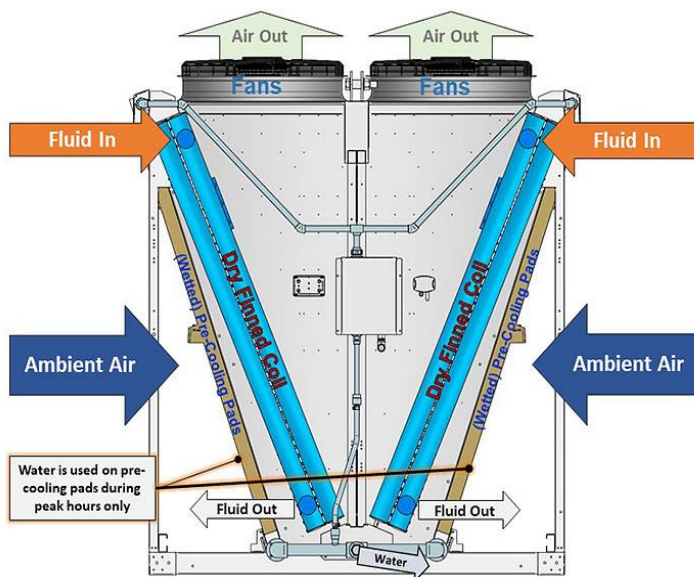


Parallel Compression



- 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

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 (CO2 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



