Natural Refrigerant Training Summit

Building a Sustainable Workforce

Hussmann TC CO_2 Evacuation, Charging and Start-Up

John Bento

Hussmann

NORTH AMERICAN Sustainable Refrigeration Council

Natural Refrigerant Training Summit

Thank you to our sponsors!

Premium Sponsors

Bitzer

Climate Pros

Copeland

Hillphoenix
A Dover Company

Basic Sponsors

AHT
a member of DAIKIN group

CAREL

energy recovery

HUSSMANN

KW
KYSOR WARREN
epta refrigeration

M&M CARNOT

Parker

SPORLAN

true

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 Carbon Dioxide	**R290** Propane	**R717** Ammonia

NORTH AMERICAN Sustainable Refrigeration Council

Hussmann CO_2 Transcritical Rack

- Basics, operation, install, maintenance

HUSSMANN®

Source Material

1. ***Installation and Operation Manual***
   - P/N 3182569
   - April 2023
2. ***TC CO_2 Sequence of Operation***
   - Booster Refrigeration System
3. ***Hussmann Transcritical Training Manual***
   - April 2018, Revision 1

HUSSMANN

About Me

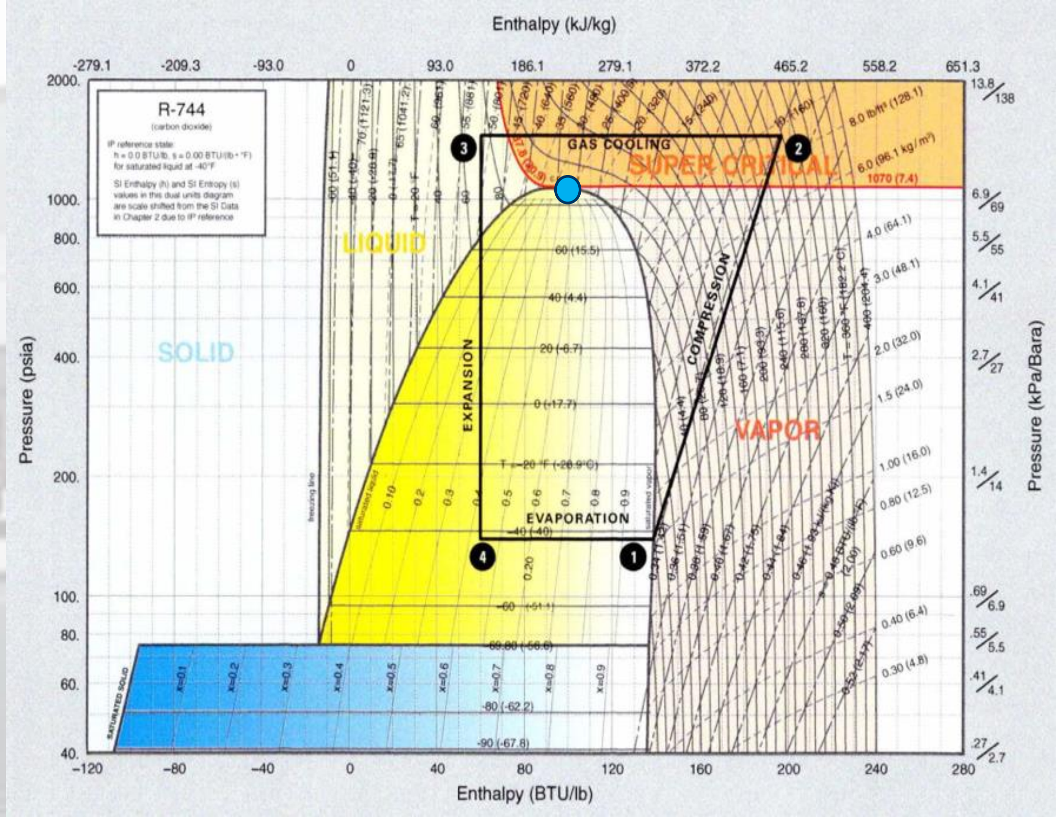
- 25+ years in Education
- 15 years teaching adult learners
- 5 years HVACR experience (US Navy)

Learning Objectives

1. Transcritical Operation
2. Components
3. Start-Up
4. Maintenance and Service

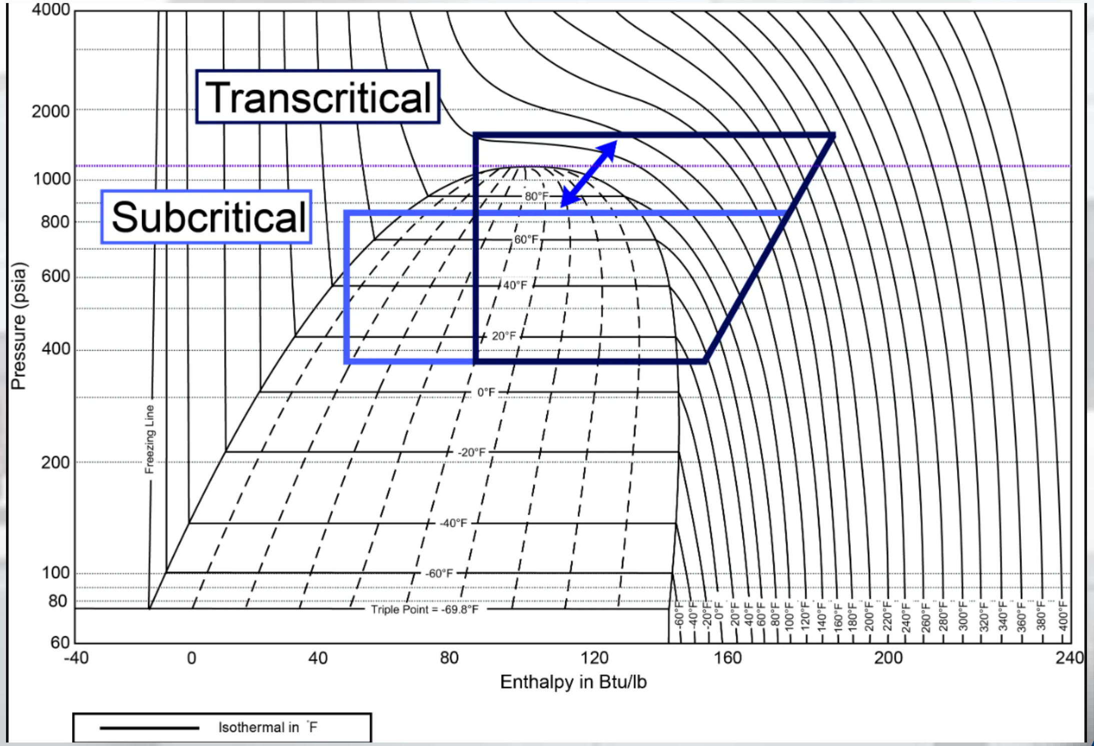
HUSSMANN®

Transcritical Systems



- Synthetic Refrigerants tend to have very high critical points
- R-22 = 70.1 C (158 F)
- R-410A = 73 C (163 F)
- R-513A = 96.5 C (205 F)
- **R-744 = 31 C !!! (87.8 F)**
- This means that CO_2 will operate in transcritical mode when the gas cooler outlet temperature is above 31 C (think Cancun, Monterrey, etc.)
- This could cause some customers to worry about an “energy penalty”

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 31C (87.8 F) The CO_2 can't condense just by the removal of heat, so the gas is cooled only.

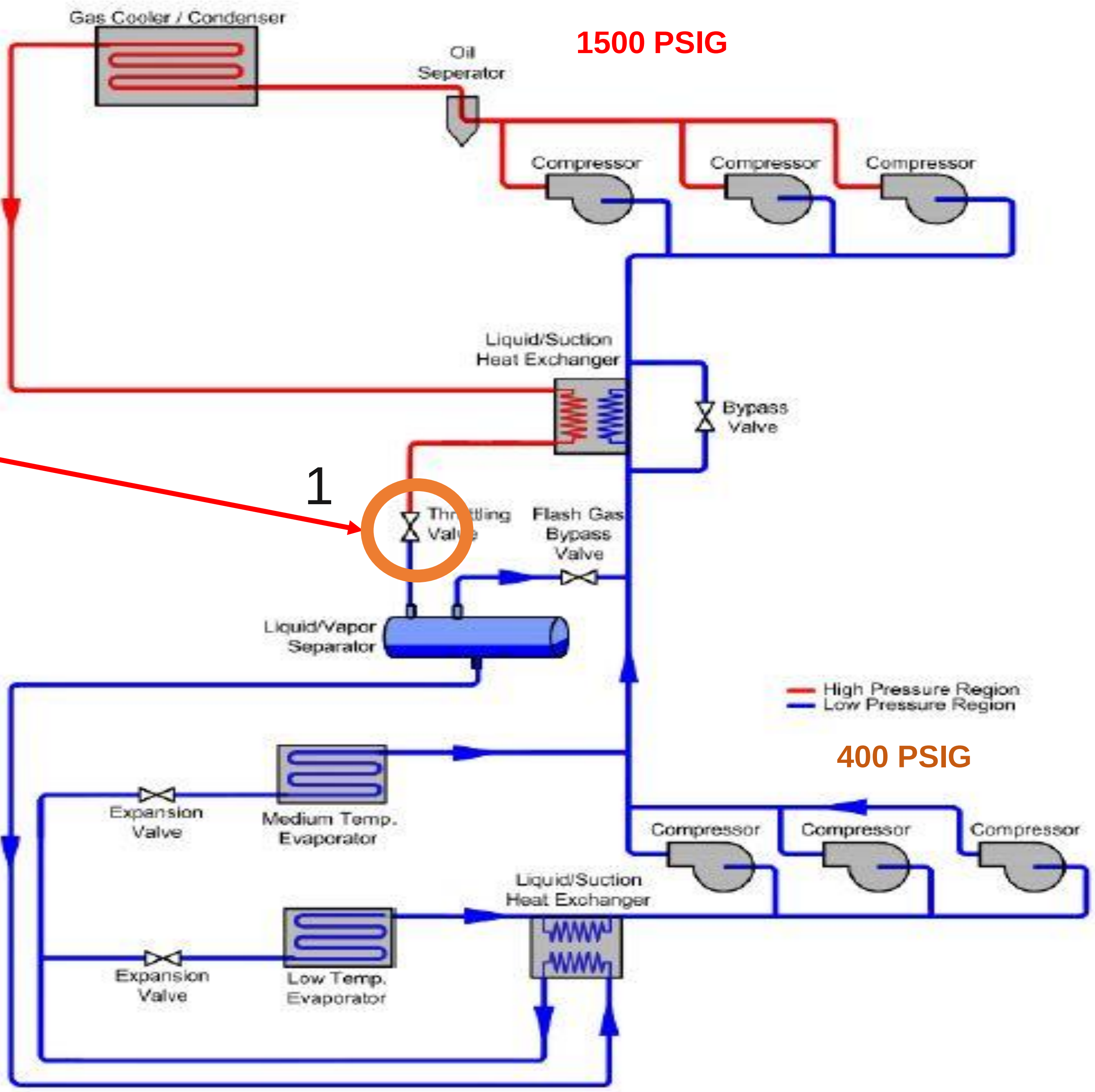
CO_2 Transcritical System Operation

- What’s different?
- System Components

HUSSMANN®

System Layout and Operation

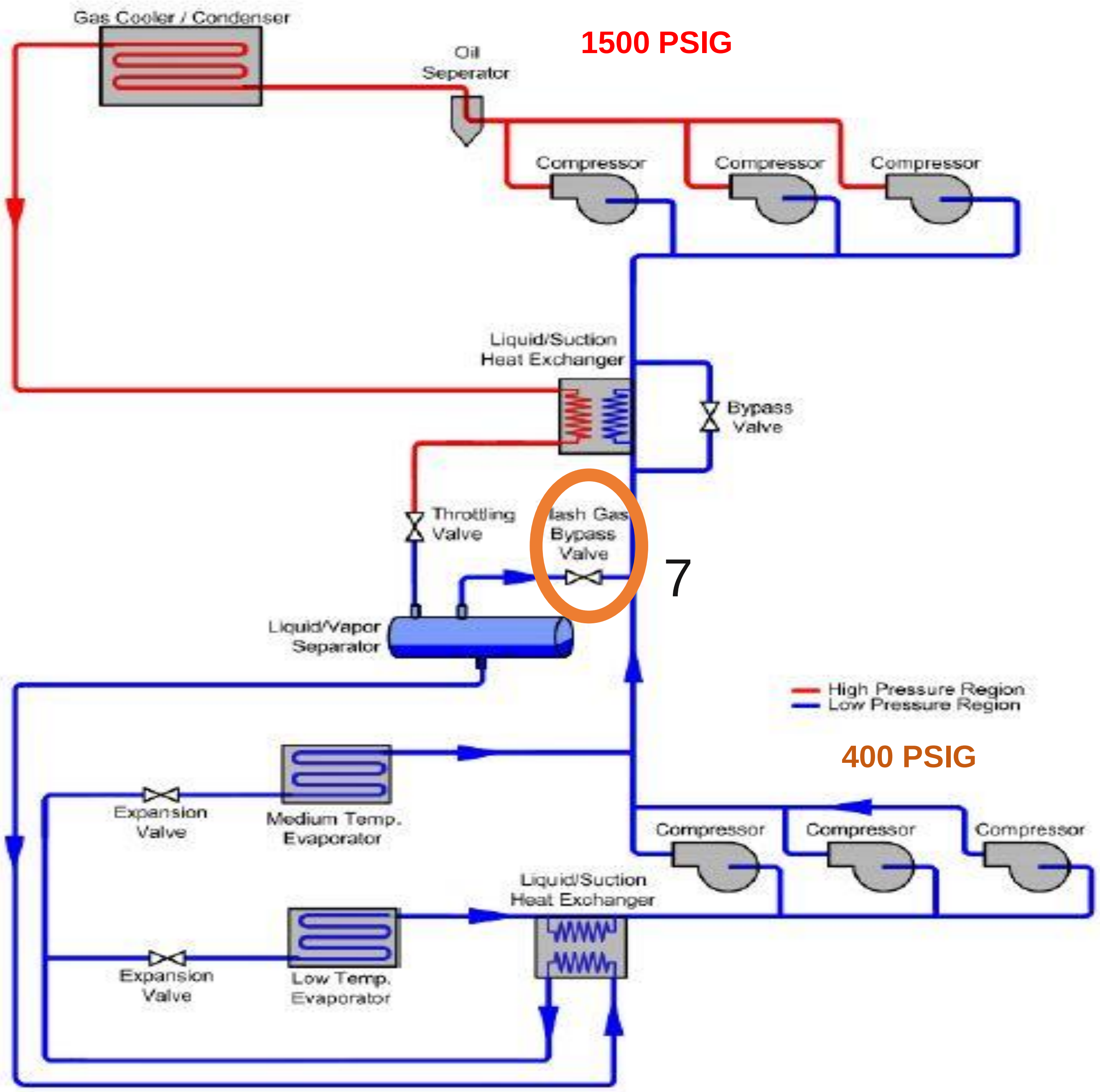
Starting at the discharge from the throttling valve (HPV) (basically a souped-up hold-back valve)…..



- Drops pressure to force a state change
- Pending on gas cooler outlet temp and pressure, fluid will be a liquid/vapor mixture
- After leaving the HPV, CO_2 enters the flash tank where it separates due to different densities.

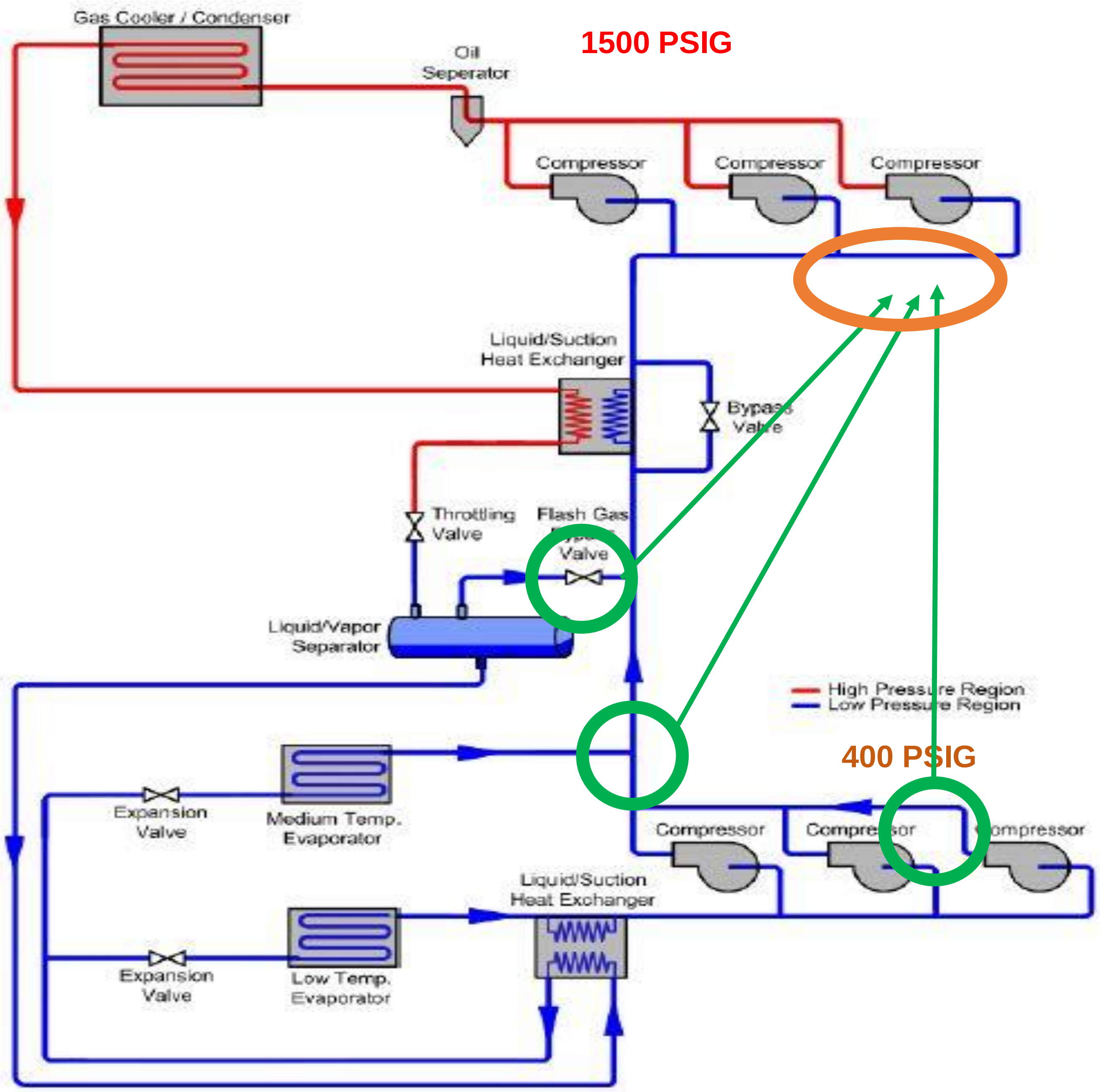
System Layout and Operation

- The flash gas bypass valve maintains the pressure in the flash tank, diverting excess vapor to the medium temp compressor suction.
- This valve also prevents liquid line pressure from going too high



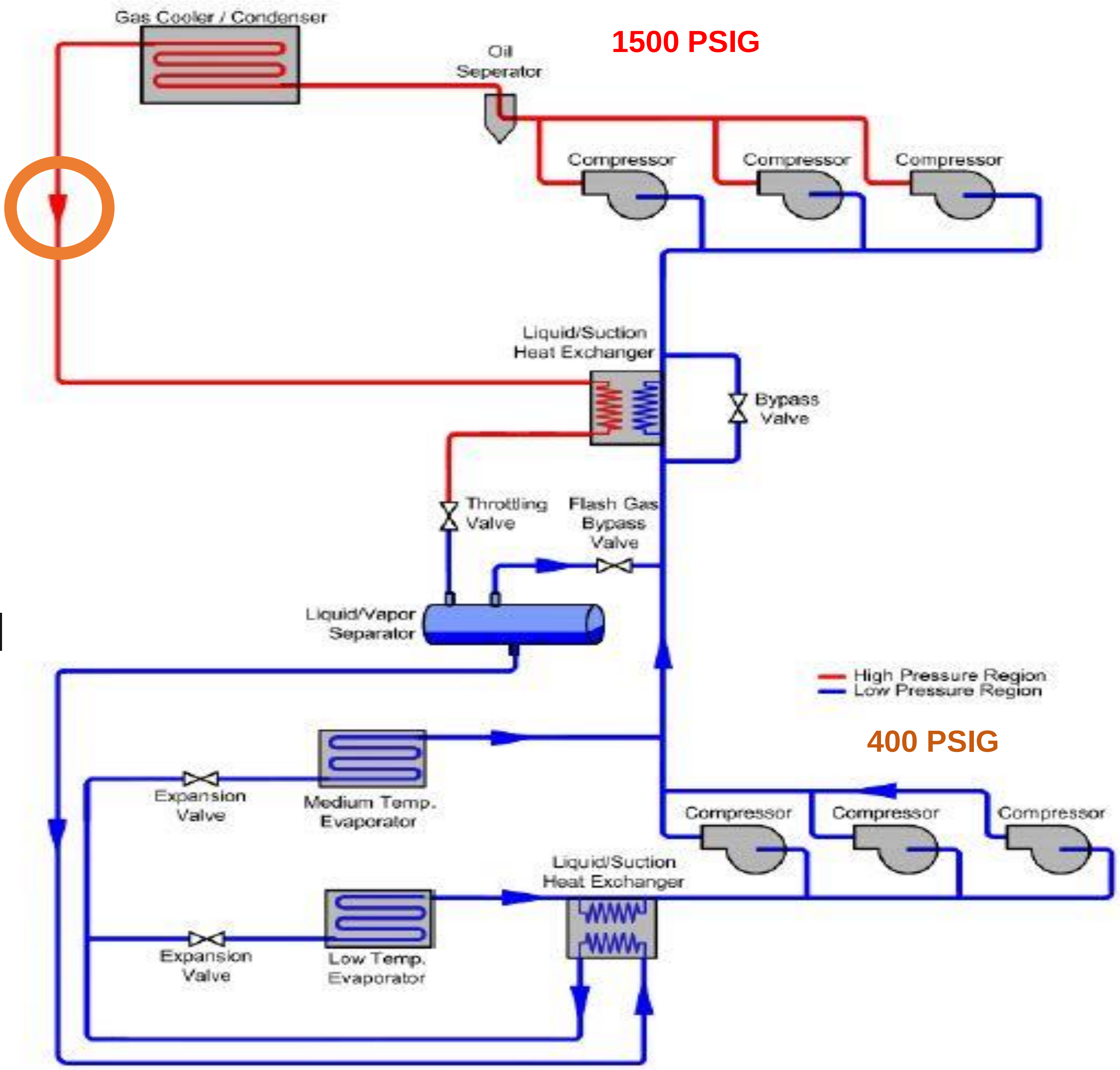
System Layout and Operation

- Medium compressor suction draws from 3 sources. There is a bit of a pressure drop from the low temp compressor discharge
- ***SH Control is critical*** due to suction gas coming from 3 sources
  - Too Low-- Poor lubrication and pulling oil
  - Too High- Oil degradation and compressor wear



System Layout and Operation

- Gas Cooler removes heat from compressed gas
- If ambient is below critical point (88 ºF), then the refrigerant will condense
- If above critical point, there will be no state change until the throttling valve
- AT and Gas Cooler outlet Temp sensors are ***most important*** for proper operation !!!!



Flash Tank

- Provides a low velocity vessel to allow for liquid and vapor to separate after leaving the throttling valve
- Low-level switch is an optical sensor that will alarm below 20%
- Sight glasses only for level indication

HUSSMANN®

Throttling/High Pressure Valve

- Responds to Gas Cooler (outlet pressure and temperature)
- Transcritical operation: maintains pressure setpoint for best performance (COP curve varies)
- Subcritical operation: maintains a subcooled liquid in the gas cooler/condenser. Typically between 3-9 $^{\circ}$F

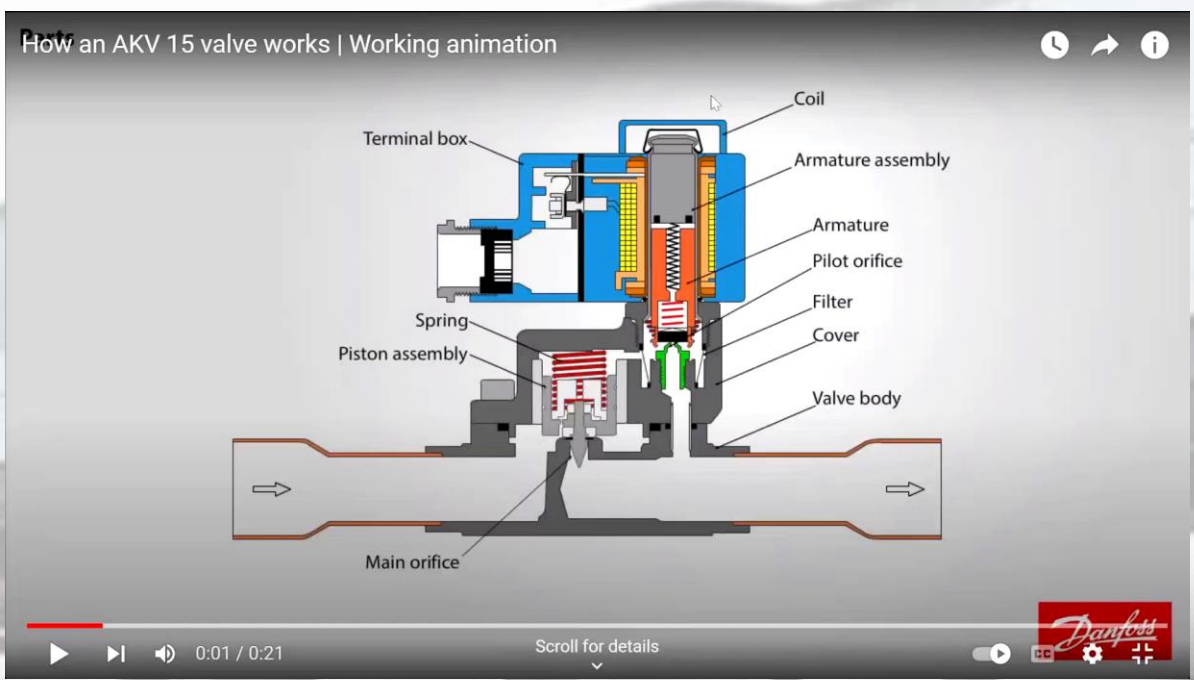
HUSSMANN®

Flash Gas Bypass Valve

- Has a static receiver pressure setpoint
- Usually closed under low load/ambient conditions
- Should maintain a pressure of at least 75 PSI above suction pressure
- Flash Tank setpoint : 500-530 PSI
- Typical operating range : 480-550 PSI

HUSSMANN®

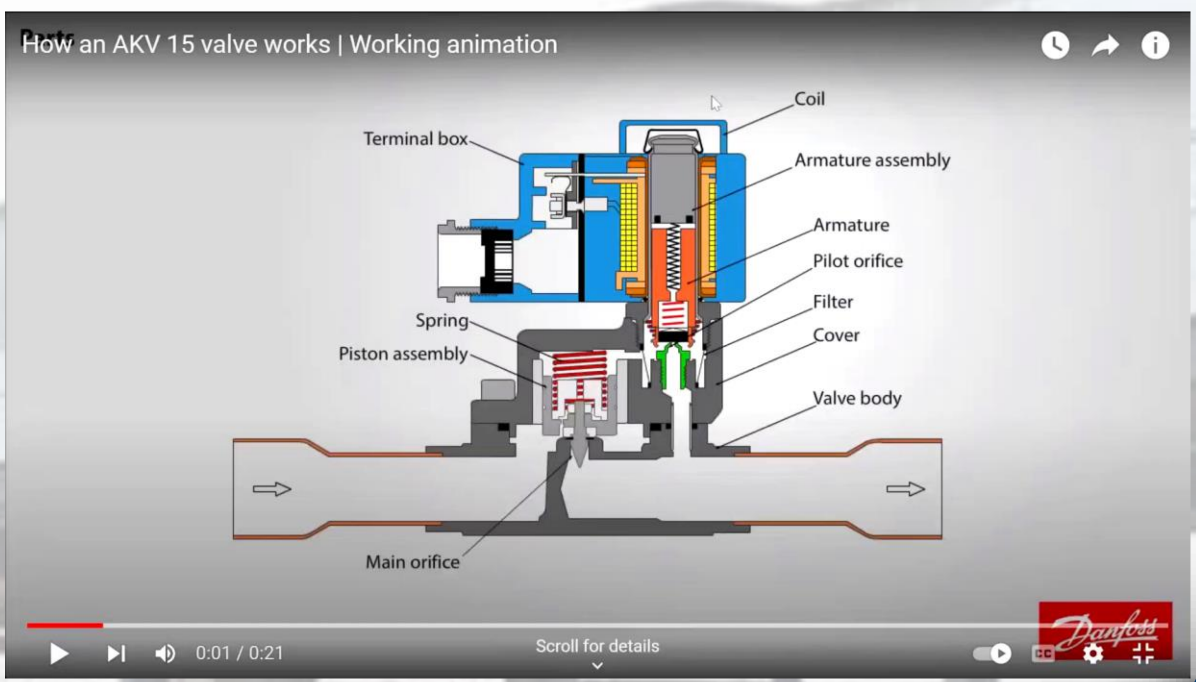
Liquid Injection Valve



- Maintains MT suction superheat if high
- Pulse width modulation valve
- Setpoints:
  - MT LI Superheat setpoint = 54 ºF
  - MT Discharge setpoint = 280 ºF
  - MT Suction Superheat Range = 20 – 40 ºF
  - MT Discharge Temperature Range = 150 – 230 ºF

HUSSMANN®

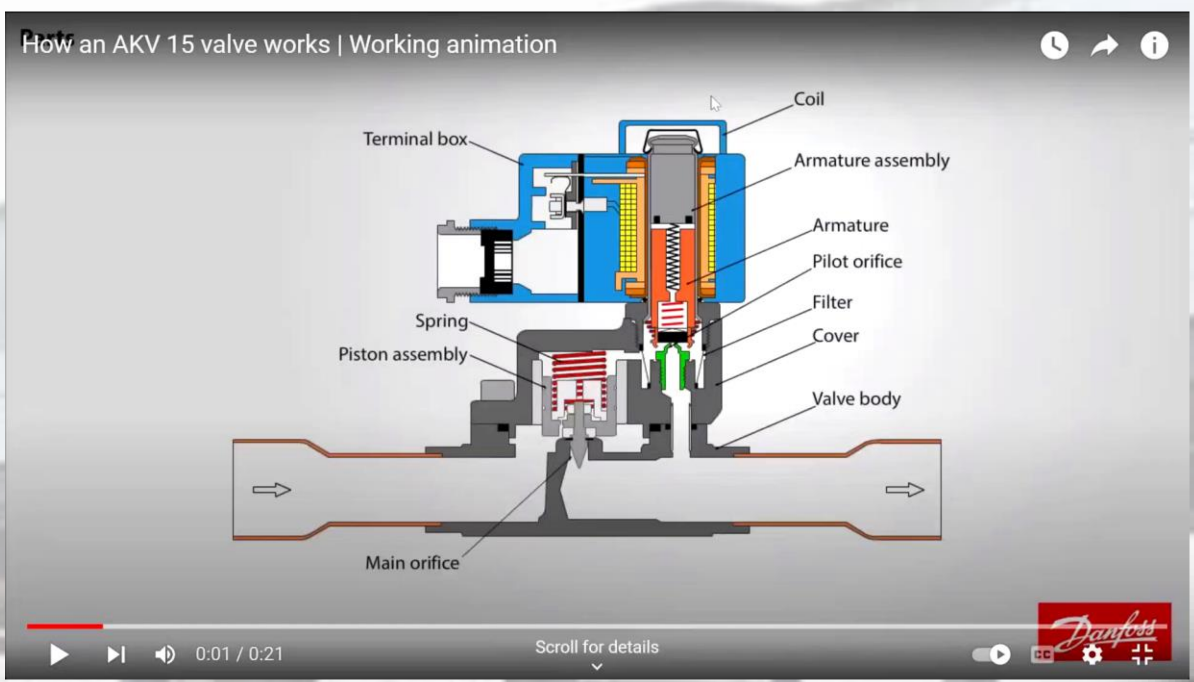
Hot Gas Dump Valve (SH)



- Maintains MT suction superheat if low
- Pulse width modulation valve
- Setpoints:
  - MT HG Superheat setpoint = 20 ºF
  - MT Suction Superheat Range = 20 – 40 ºF
  - Superheat alarm setpoint = 10 ºF

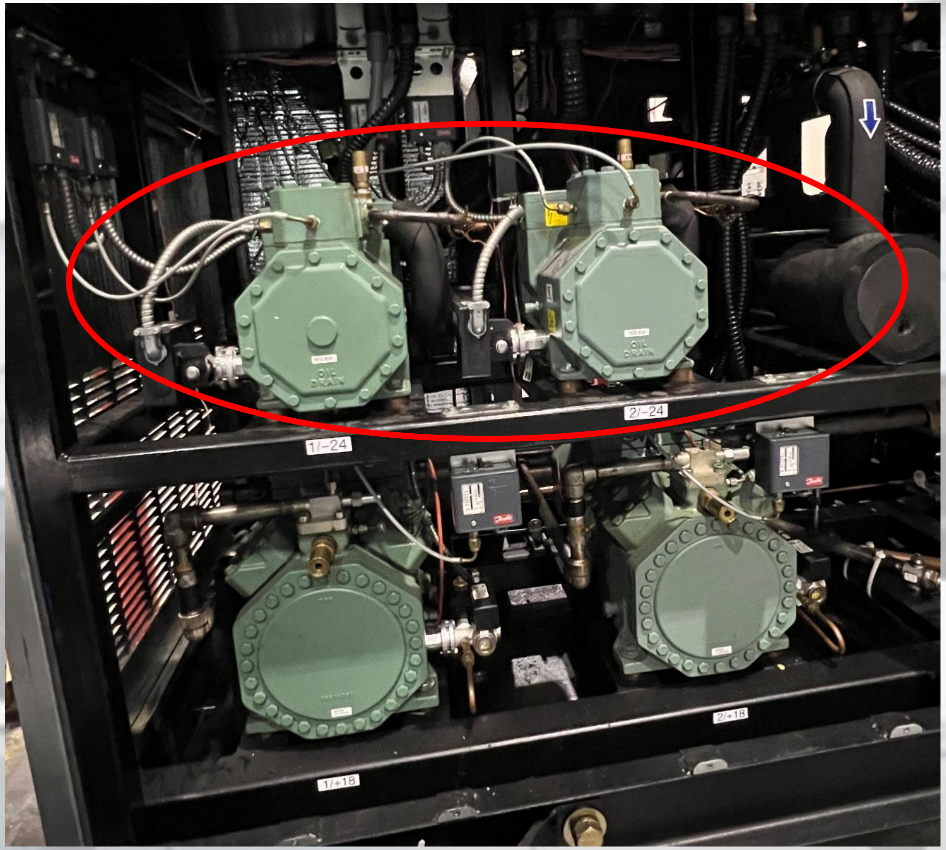
HUSSMANN®

Hot Gas Dump Valve (Flash Tank)



- Maintains Flash Tank pressure if low
- Pulse width modulation valve
- Setpoints:
  - Flash Tank HG setpoint = 460 PSIG
  - Flash Tank HG setpoint differential (typical) = 30 PSIG
  - Superheat alarm setpoint = 10 ºF

HUSSMANN®



HUSSMANN®

Compressor Staging

- Low Temp (-20 ºF) and Medium Temp (20 ºF)
- Typically maintains suction pressure corresponding to load and other conditions (about +/- 7 F)
- Setpoints:
  - LT Pumpdown = 162 PSIG
  - LT Suction Pressure Range = 162 – 208 PSIG
  - MT Pumpdown = 328 PSIG
  - MT Suction Pressure Range = 328 – 420 PSIG

System Operation

- Low temperature compressors discharge into the medium temperature suction
- The extra heat of compression helps to manage Medium temp superheat (CO_2 systems have a higher SH, 36 - 52 ºF)
- Medium temperature suction groups must have at least one compressor operating for the low temp compressors to run
- Each suction group has at least 1 VFD compressor

Parameter	Value	Unit	Notes
MT Low Suction	345	PSIG	Failure & Alarm
LT Low Suction	160	PSIG	Failure & Alarm
MT High Suction	475	PSIG	Alarm Only
LT High Suction	290	PSIG	Alarm Only
MT High Discharge	1522	PSIG	Failure & Alarm
LT High Discharge	490	PSIG	Failure & Alarm
MT Discharge (range)	600 – 1300	PSIG	Typical Range
LT VFD (range)	30 – 75	Hz	Typical Range
MT VFD (range)	25 – 70	Hz	Typical Range
Minimum off time	1	Minute	Typical Setting
Hourly cycles	6	Starts/Hr	Typical Setting

*** Typical Suction Group Parameters**

Compressor Control

- Each panel has controls that can electrically isolated and allow the other compressors to continue running:
  - Electrical control
  - Low and high-pressure switches
  - Oil pressure switch
  - Contactor coil
  - Overload contact (if used)
  - Crankcase heater

HUSSMANN®

Oil Management

- Two oil management areas :
  - Oil separator draining (rack controlled)
  - Compressor oil level (locally controlled)

HUSSMANN®

System Operation

- When the separator signals a high oil level, the rack controller will pulse the oil drain solenoid
  - Pulsing ensures that oil can be drained but not so much that hot gas will go to the flash tank
- Compressors have Emerson OMC oil level controls
  - When oil level drops, the OMC will energize the oil solenoid to fill the compressor
  - If unable to fill the compressor, the OMC will shut down the compressor.
  - The rack controller will generate an alarm

Parameter	Value	Unit	Notes
Oil Separator Drain Pulse Time	15	Seconds	
Oil Separator Drain Time	45	Seconds	
Oil Pressure (typical)	490 - 550	PSIG	Maintain 80 PSI above MT Suction
Oil Drain Cycles (typical)	20 - 40	Per/hr	

*** Typical Oil Management Parameters**

Pressure Relief Valves

- Low Temperature Suction = 435 PSI
- Medium Temperature Suction = 650 PSI
- Flash Tank (Liquid Line) = 650 PSI
- Medium Temperature Discharge (high side) = 1740 PSI
- Due to the high pressures, all system relief valves are piped to the roof
- If they lift, evaluate before changing them!

HUSSMANN®

HUSSMANN®

Gas Cooler Fan Control

- Rack Controller monitors ambient, pad (adiabatic), and gas cooler outlet temperatures
- Controller calculates temperature difference and adjusts fan speed to maintain the ∆T (typically about 10 ºF)

HUSSMANN®

Case Controllers

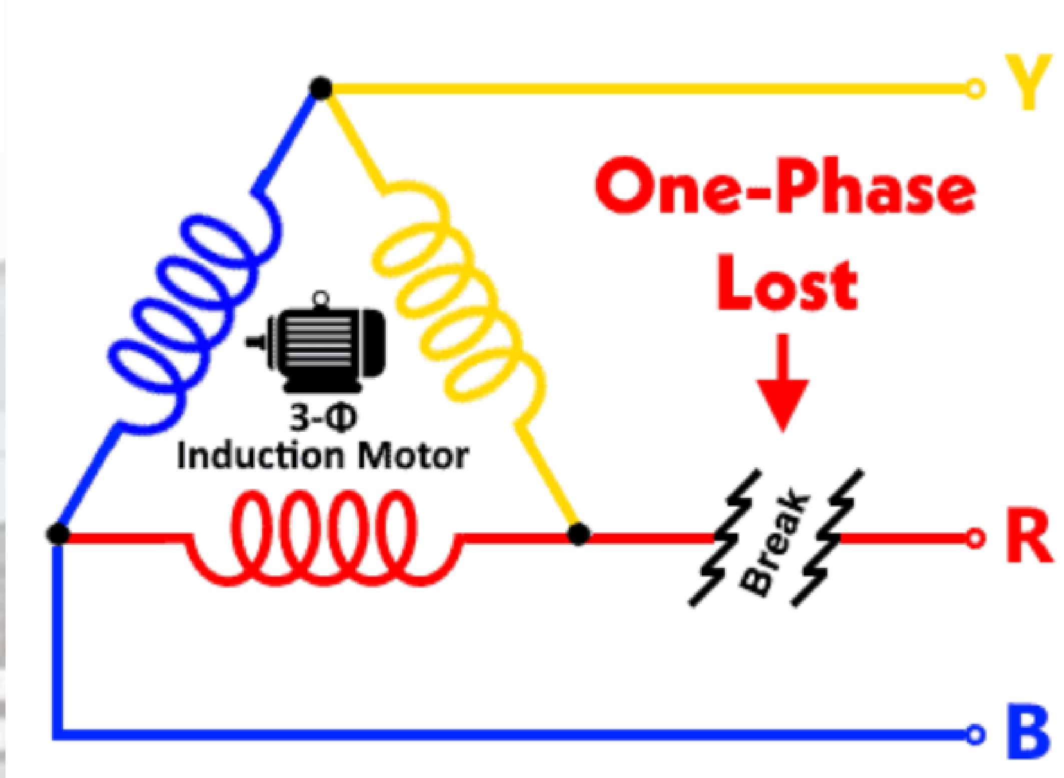
- Maintains the case temperature and superheat in the case by using the EEV
- Has a MOP (maximum operating pressure) that, if exceeded, will close the EEV

System Operation

Parameter	Value	Unit	Notes
LT Case Controller MOP Setpoint	290	PSIG	Typical Setpoint
MT Case Controller MOP Setpoint	475	PSIG	Typical Setpoint
Case Controller Superheat	8 – 20	º F	Typical Operating Setpoint
Case Controller Superheat Band	8 – 15	º F	Typical Superheat Band Range
Case Controller Superheat Cut Out	4	º F	Typical Superheat Cut Out Setpoint

***Typical Case Controller Setpoints and Operating Parameters**

***Superheat will be different depending upon LT or MT Cases**



HUSSMANN®

Phase Loss

- Phase loss can be caused by many issues
- The result is a shutdown until the emergency event is cleared
- To test during start-up, remove one leg, ensure that the unit shuts down
- This is instantaneous

Phase Loss

- A PLM is a digital input to rack controller that will close when voltage is outside normal range
- During the event all compressors will be kept off until the event clears
- To limit temperature and pressure increase of the refrigerant charge, the following conditions apply:
  - HPV & FGB will be shut
  - Defrosts disabled
  - Evaporator fans off
  - EEV’s closed
- After the event clears, the rack will attempt a staged restart
  - Generally, 15-25% of circuits will come on per stage
  - Order of circuits brought on-line generally are from most critical to least

System Start-up

- Leak testing, Evacuation, Charging, Oil, etc.

HUSSMANN®

Leak Testing

- Both the rack and the system as a whole must be leak tested before evacuation

HUSSMANN®

GreenChill Best Practices Guideline

Ensuring Leak-Tight Installations of Commercial Refrigeration Equipment

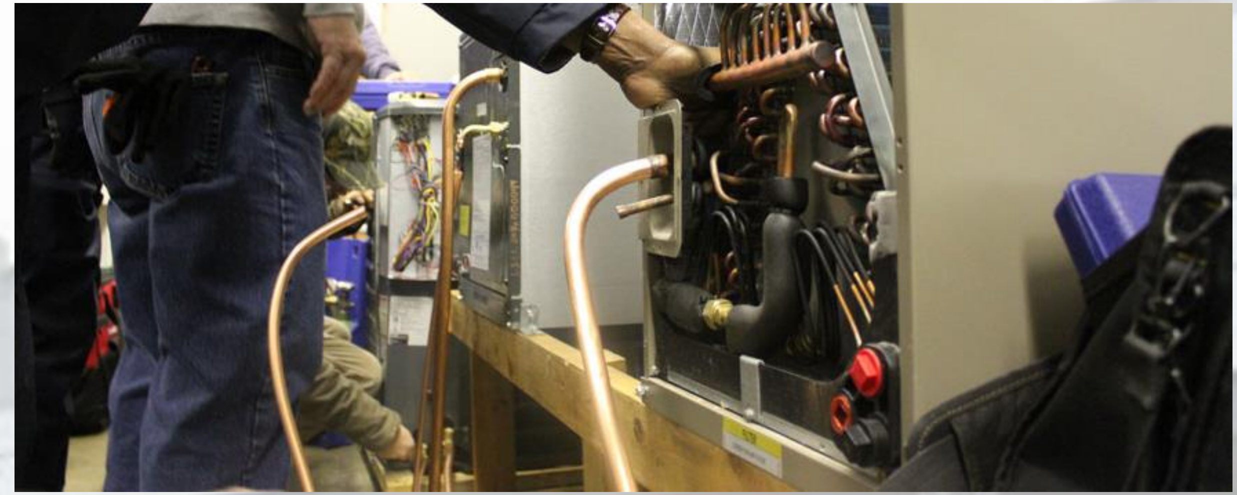
U.S. Environmental Protection Agency
Stratospheric Protection Division

HUSSMANN®

Leak Testing

- Charges should be held for 24 hours
- Due to the high operating pressure of CO_2 systems, standard pressure tests are:
  - LT Suction = 350 PSI
  - MT Suction/Liquid = 525 PSI
  - MT Discharge/Drain = 1400 PSI

https://www.epa.gov/sites/default/files/documents/leakguidelines.pdf



System Evacuation

- Evacuation removes moisture, air, and other non-condensables from the system prior to charging with refrigerant

HUSSMANN®

System Evacuation

- Ensure that the system has passed its leak test
- Ensure pumps are in proper working order
- Ensure all valve packings are tightened
- Ensure liquid filters are installed before 3rd pull
- Crankcase heaters on
- All pump connections should be non-collapsible
- Ensure that all transducers are valved off as high vacuums can damage the sensors
- Charge oil during the 1st or 2nd evacuations
  - Compressors to half a sight glass
  - Reservoir to ½ full
- Ensure all caps on the rack are tightened (NO PLASTIC)

System Evacuation

- A maximum of 2 vacuum pumps are allowed, with a total capacity of ***at least*** 10 CFM (the stronger pump will always win)
  - A single pump of 25 CFM is preferred
- A Vacuum will be pulled 3 times:
  - 1st will be down to 1000 microns
  - 2nd will be down to 500 microns
  - 3rd and final vacuum will be held at 300 microns for 24 hours
- Pump oil should be changed after both the 1st and 2nd evacuations

Charging the System

- Due to its physical properties, CO_2 charging must be done in 2 stages: First with gas, and then with liquid

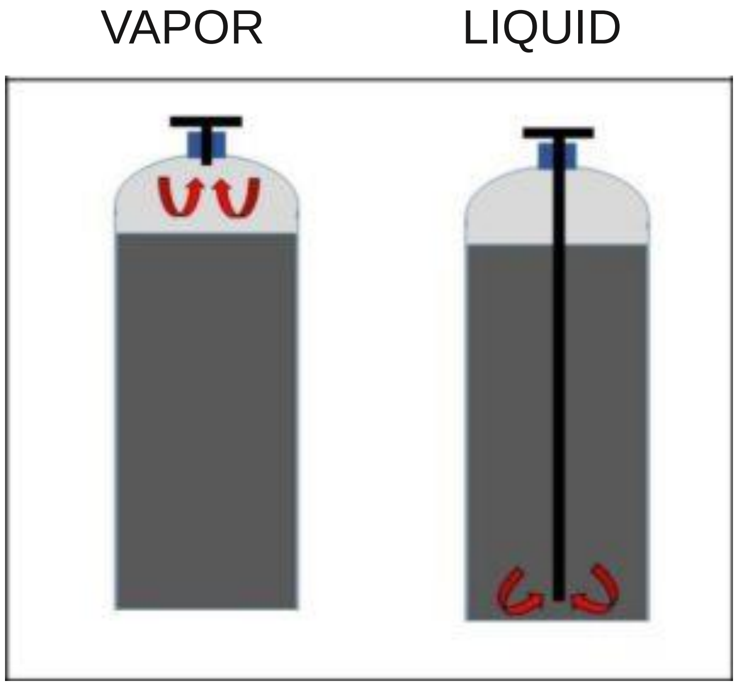
HUSSMANN®

Charging the System

- Prior to charging check the following:
  - Case sensor/transducer placement
  - Electrical checks (tight connections, cleanliness, vacuum any loose metal shavings)
  - Proper fan operation and rotation
  - Case controller settings/adjustment
  - Walk-in electricals (lights, fans, etc.)
  - Damper operation (if equipped)
  - Heat reclaim and other systems
  - Gas Cooler controls
  - Defrost schedule and timing
  - Ensure HPV and FGB are working (cycle them)

Charging the System

- CO_2 has a low tolerance for moisture and will form carbonic acid which can corrode piping and components
- Hussmann recommends a purity of “Bone Dry” (99.8%) or higher
- Most “Refrigerant Grade” CO_2 is 99.99% pure and has <10 PPM moisture content



Charging the System

- CO_2 cannot exist as a liquid below 5.11 atmospheres (75 PSI)
- Charging the system with vapor up to 80 PSI prevents the formation of dry ice in the system
- Open compressors: backseat service valves
- Open oil supply line downstream of the oil separator
- Pressure transducers – open angle valves
- Leave open ball valves – to branches, gas cooler, heat reclaim, flash tank
- Set all mechanical pressure controls
- Charge system through an in-line filter/drier with vapor to 80-100 PSI
- Before adding liquid, check transducer function and case controller feedback (this will make start-up much smoother)

Charging the System

- After fixing any bad transducers or communication issues, proceed to liquid charging
- Pump down the system as you charge
- Close flash tank outlet and float 3 sight glasses
- Cease charging and open the flash tank outlet
- More charging may be needed as more loads come on-line

**Phase change using only pressure change

Start-up Sequence

HUSSMANN®

3/8/2024

Start-up Sequence

- ***At least 40% (this is the bare minimum and may not be enough!)*** of the load should be available prior to starting
- Perform a phase loss test to make sure all case EEV's shut down
- Leak detectors tested in walk-ins
- Start the medium temp compressor
- Continue to charge the system as needed
- All running compressors must be attended until system is fully charged with refrigerant and oil
- **NOTE**: In new construction, set LT setpoints at 35 ºF for 48 hours to pull moisture out of the boxes. Then drop to 10 ºF for 24 hours. Then, set to recommended setting. (Customer's parameters will supersede this)

What to Monitor During Start-up

- Monitor for flood-back from controller parameters
- Watch oil levels in both the compressors and reservoir
- Make sure flash tank does not exceed 600 PSI
- Leave in Suction filters
- Ensure oil differential is set to at least 60-80 PSI (swedgelock only) above medium suction pressure (adjust if necessary). Hussmann has found that 80 PSI above medium suction is optimal

After Start-up

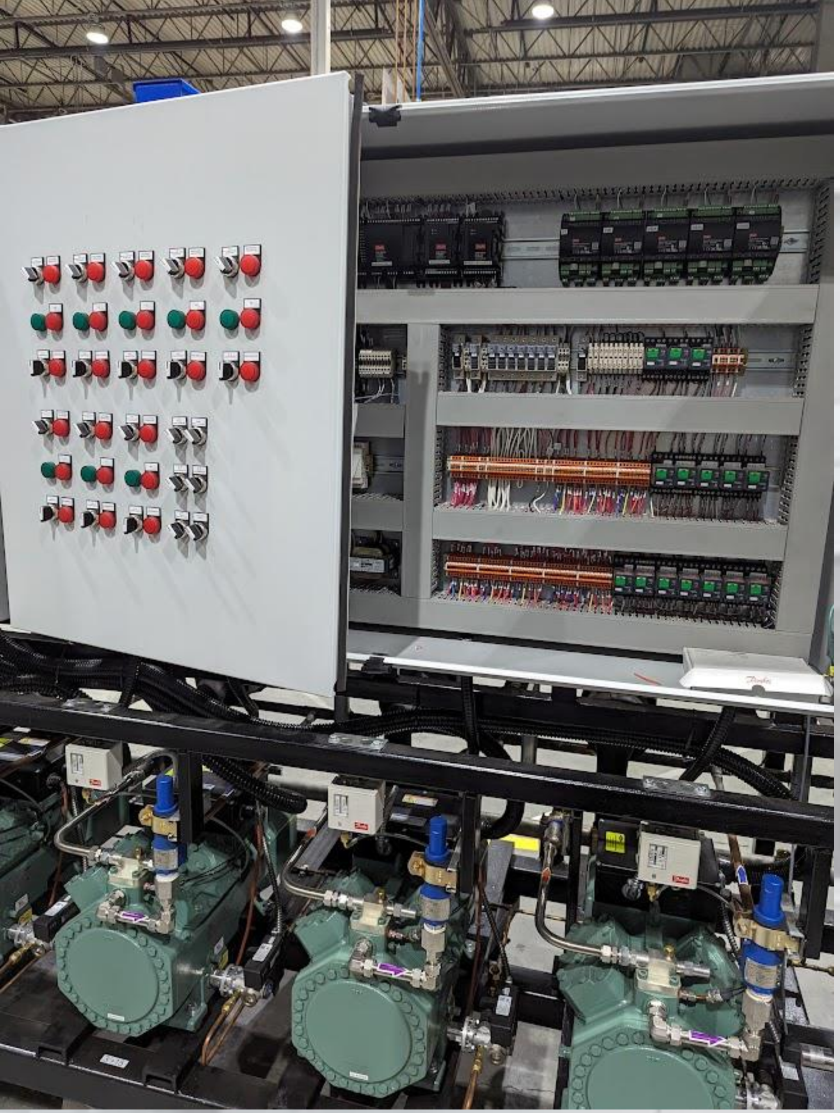
- Top off the oil charge
- Change the oil, filters, suction and liquid filters within 30 days (this should be done ASAP)
  - If customer has different requirements, they overrule this point
- Anytime after this point when the system is opened, drier cores must be replaced
- Leak test with a sniffer
- Verify defrost schedule is functioning properly
- Check case temperature and coils after defrost
- Fix any programming issues
- Verify sensors and transducers for calibration
- Record CO_2 level once system is stable
- Record and record amp draw on all 3 legs for each compressor
- Complete commissioning document

Other Checks on Day 1

- Review compressor cycle counts (no more than 6 per hour)
- Review HPV & FGB for excessive modulation
- Verify oil separator drain solenoid is cycling properly
- Check ΔP across the oil separator. Replace if greater than 10 PSI
- Clean oil supply line strainer
- Verify evaporators and compressor superheats

Checks on Day 3

- All Day 1 checks
- Replace liquid and suction filters (some operators wait for 7 days)
- Test oil for moisture and acidity



Maintenance Schedules

- These are Hussmann recommendations ONLY
- Customer prescribed maintenance schedules supersede the following pages

HUSSMANN®

Weekly Checks

- System Pressures
- Main Power Voltage
- Oil Levels
- Flash Tank CO_2 Level

Monthly Checks

- Oil Separator ΔP
- System Pressures
- Leak Testing
- Filters and Drier Cores (evacuate before re-pressurizing)
- Secondary Systems
- Insulation damage, Electrical Connections

Quarterly Checks

- Suction, Liquid, and Discharge Pressures and Temperatures
- Sub-cooling, Superheat, and Ambient Temperatures
- Safety Controls, Operating Controls, & Alarms
- Compressor Amperage

Annual Checks

- Clean Gas Cooler and Pads (Adiabatic)
- Change Filter Drier and Suction Cores
- Take Oil Sample, Change if Necessary

End of Deck