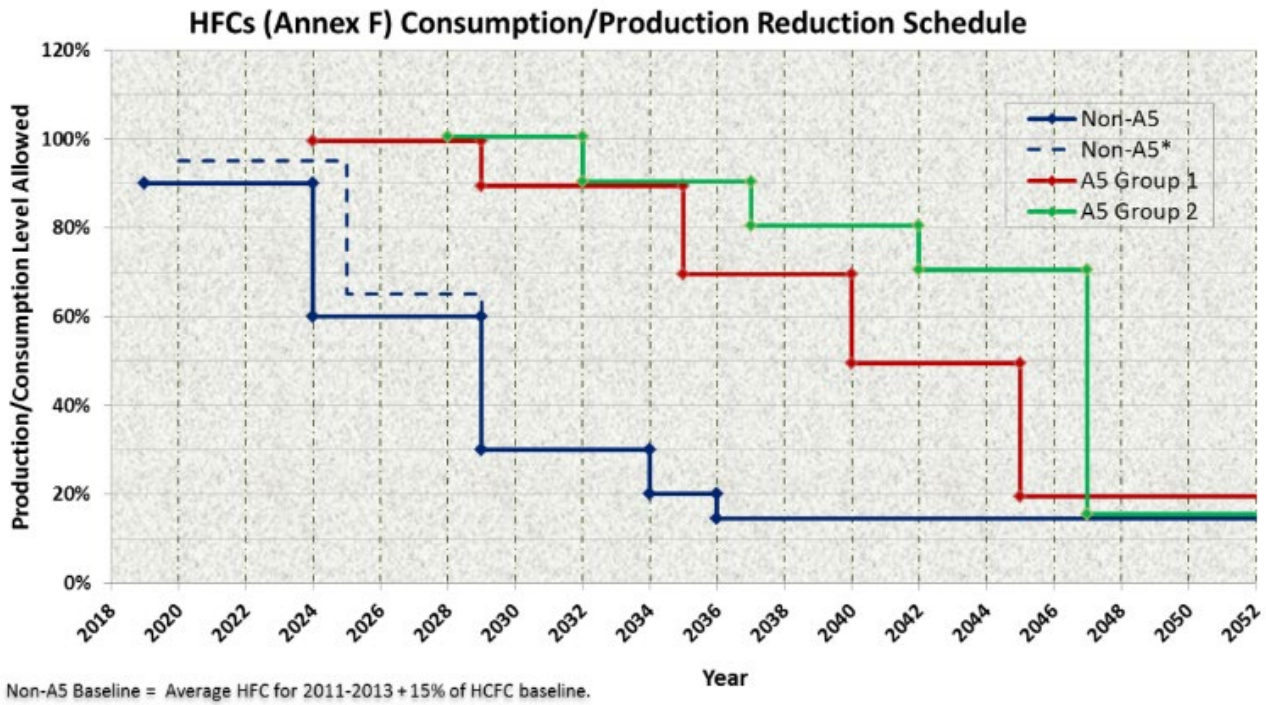
Contractor Perspective on CO2 Refrigeration

South-Town
REFRIGERATION & MECHANICAL

SCR®



- Amendment to Montreal Protocol (ODP phase out, CFCs, HCFCs)
- Limits use of HFCs globally through stepped phase down

Kigali Amendment

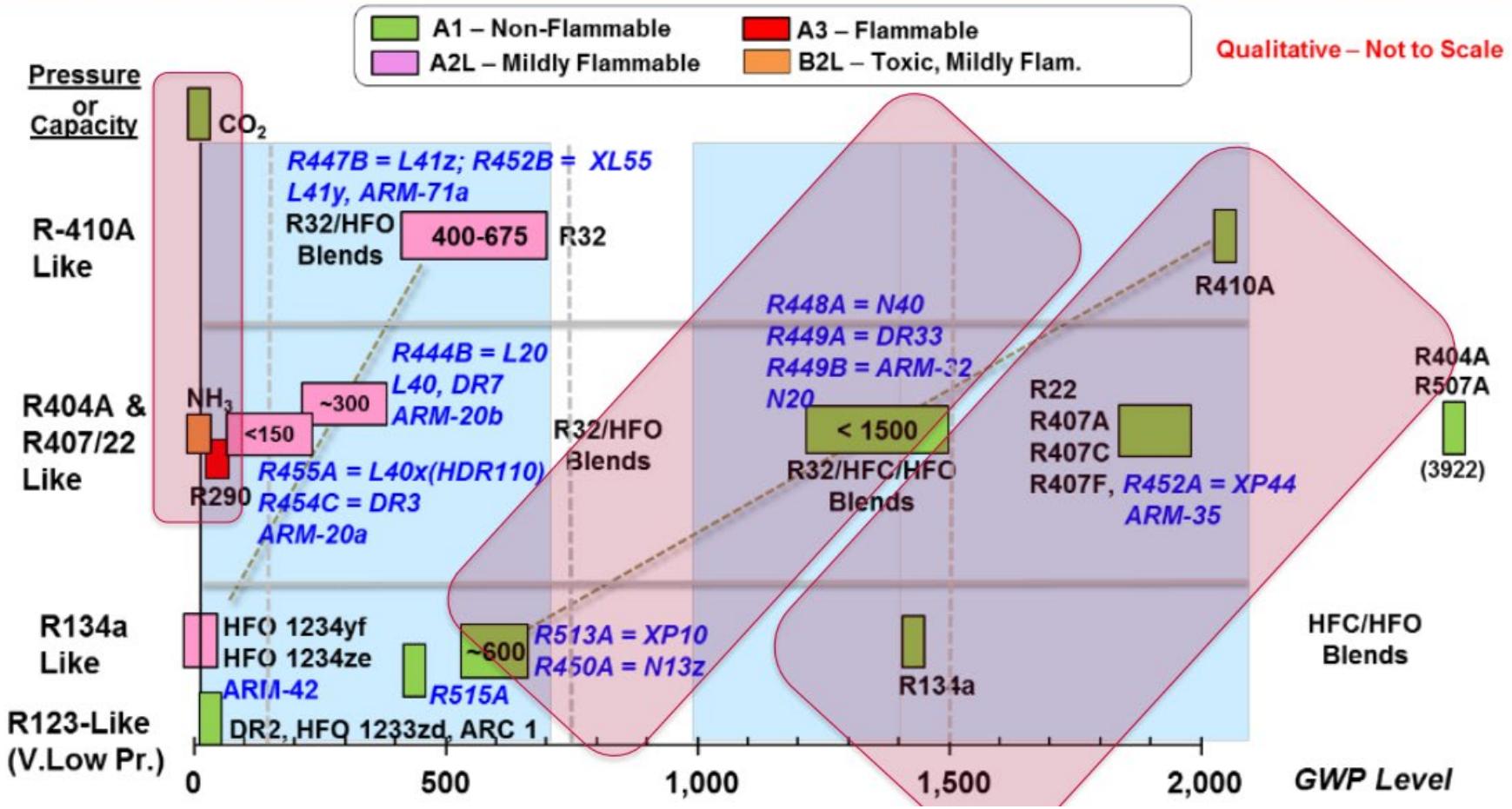
AIM Act

- Final rule signed 10/5/23.
- Act phases out higher GWP refrigerants.
- Ice Rinks 1/1/25 (GWP < 700)
- Cold Storage & Industrial 1/1/26 (GWP < 150, 300 200lb limit)
- Retail Food Condensing Units 1/1/26 (GWP < 150, 300)
- Chillers 1/1/25 comfort cooling, Industrial 1/1/26 (GWP < 700)
- End game is natural refrigerants and A2L's.

AIM Act

Refrigerant	GWP*
R-717 (Ammonia)	–
R-744 (Carbon Dioxide)	1
R-290 (Propane)	4
HCFC-123	77
R-448A	1,386
R-449A	1,396
HFC-134a	1,430
HCFC-22	1,810
R-407F	1,825
R-404A	3,922
CFC-11	4,750
CFC-12	10,900

AIM Act


A1 – Non-Flammable
A2L – Mildly Flammable
A3 – Flammable
B2L – Toxic, Mildly Flam.
Qualitative – Not to Scale
Pressure or Capacity
CO2
R447B = L41z; R452B = XL55
L41y, ARM-71a
R-410A Like
R32/HFO Blends
400-675
R32
R410A
R448A = N40
R449A = DR33
R449B = ARM-32
N20
R444B = L20
L40, DR7
ARM-20b
R404A & R407/22 Like
NH3
~300
<150
R290
R455A = L40x(HDR110)
R454C = DR3
ARM-20a
R32/HFO Blends
< 1500
R32/HFC/HFO Blends
R22
R407A
R407C
R407F, R452A = XP44
ARM-35
R404A
R507A
(3922)
R134a Like
HFO 1234yf
HFO 1234ze
ARM-42
~600
R513A = XP10
R450A = N13z
R515A
R134a
HFC/HFO Blends
R123-Like (V.Low Pr.)
DR2, HFO 1233zd, ARC 1
0
500
1,000
1,500
2,000
GWP Level

AIM Act (Legacy Systems)

- Assembling a system for the first time from used or new components.
- Increasing the cooling capacity of the system.
- Replacing 75% of the evaporators (by number).
- Replacing 100% of the compressor racks, condensers, and connected evaporator loads.

CO2

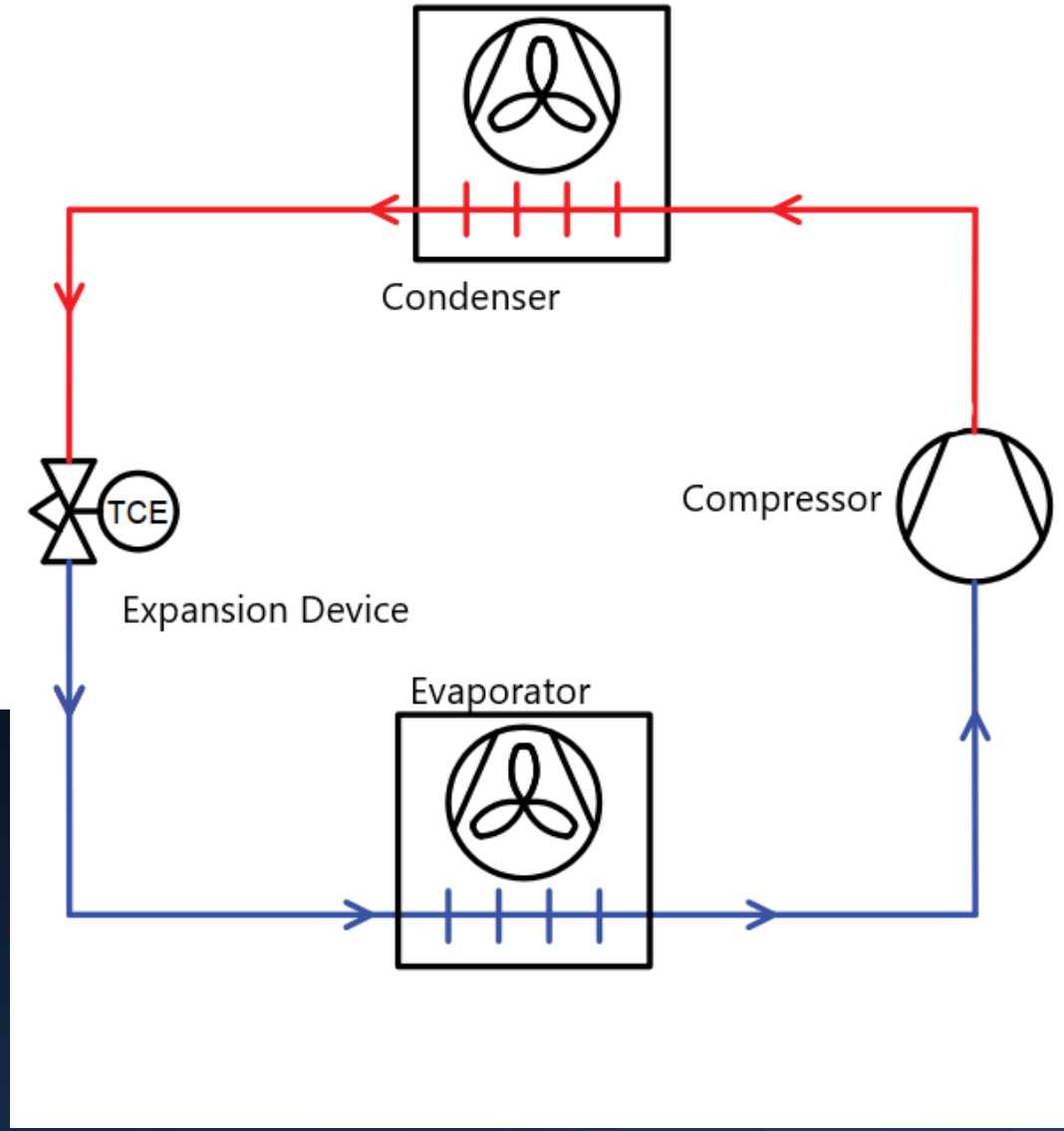
- Choice for the future.
- Not subject to phase out.
- Low cost refrigerant.
- A1 safety classification.
- Refrigerant lines are typically smaller than HFC systems.
- High pressure refrigerant.
- Efficient.
- Instrument, Coleman, or Refrigerant grade.

System Design

- Booster System vs traditional
- Oil separation
- Subcritical (pros & cons)
- Transcritical (pros & cons)
- Pipe ratings (lower if we use CU for keeping pressure down – on a generator)
- Work with engineering prior to building systems.
  - Discuss location of rack
  - Sizing of loads
  - Etc.

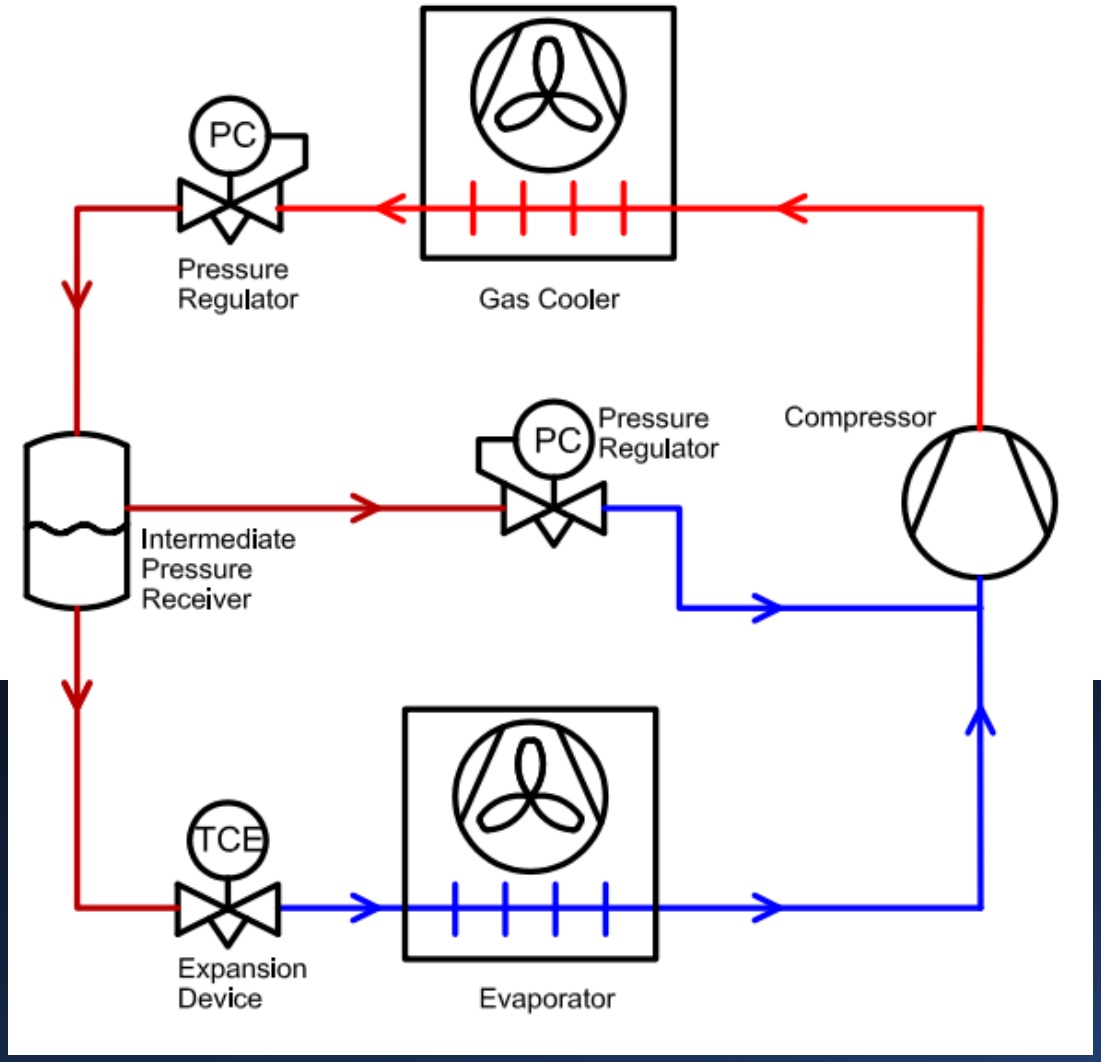
Halocarbon Example Design

Simple halocarbon system architecture



CO2 Single Stage Transcritical Design

Transcritical 744 system architecture



R-404a Sample PH Diagram 80F Cond, 20F SST

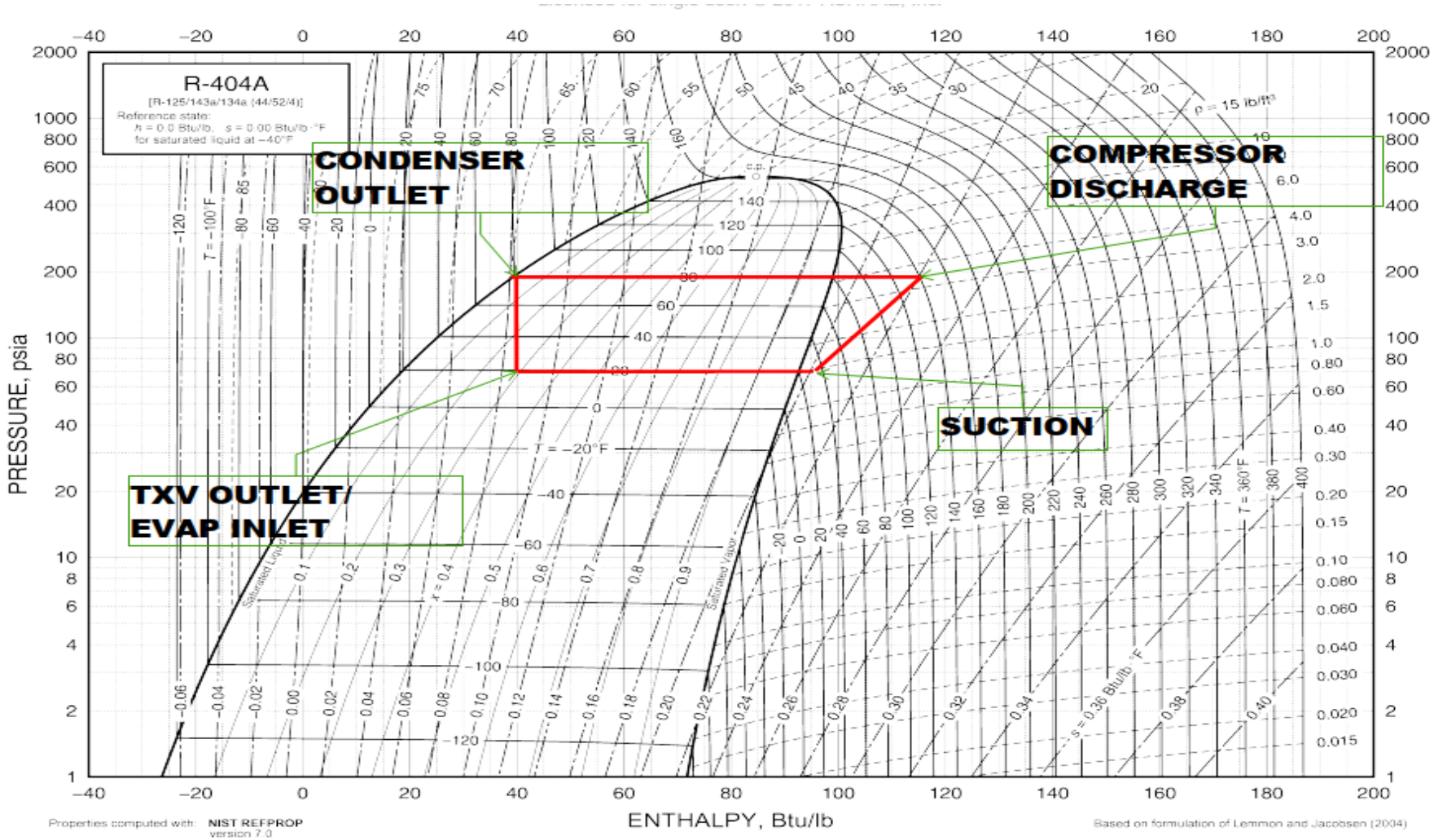
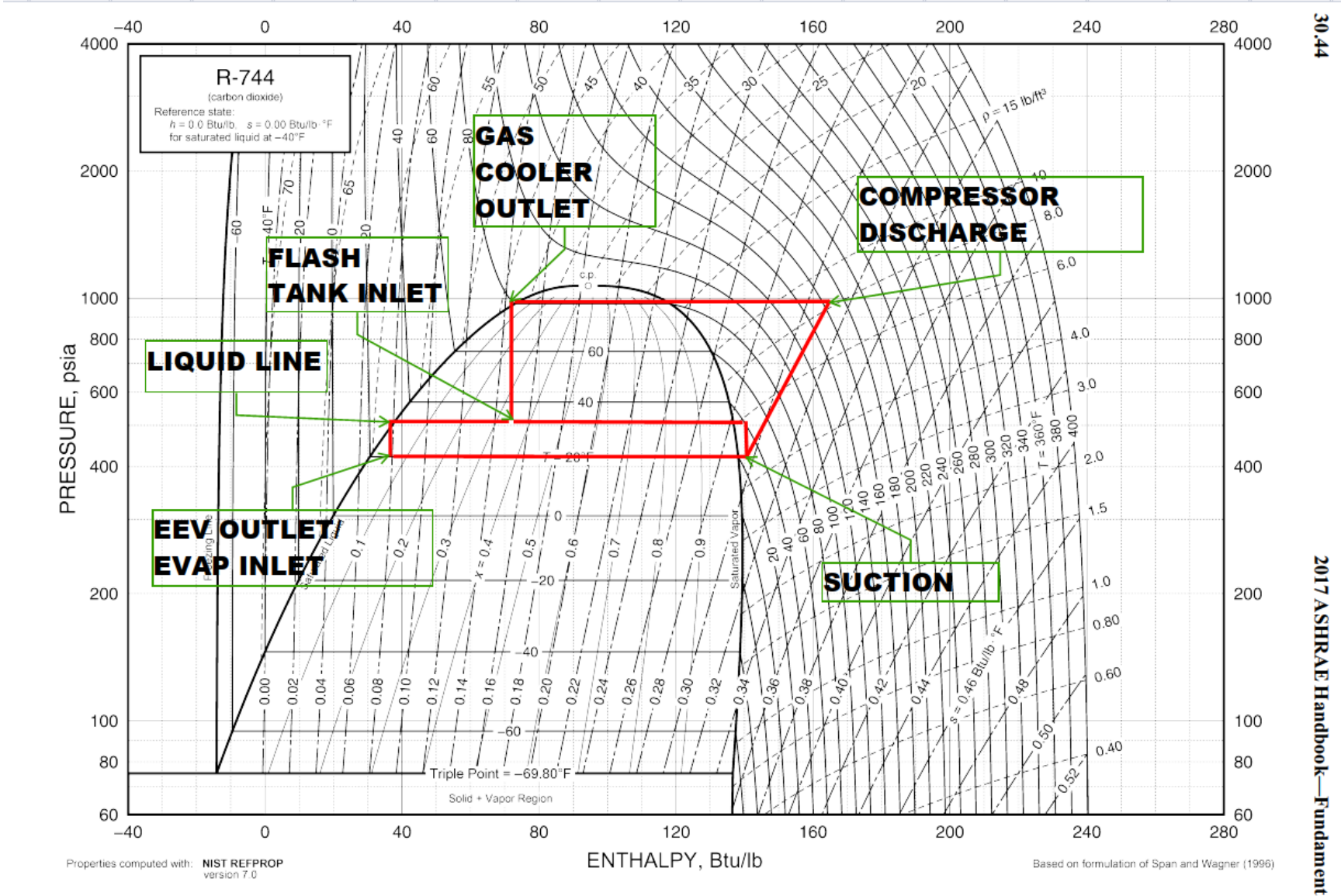
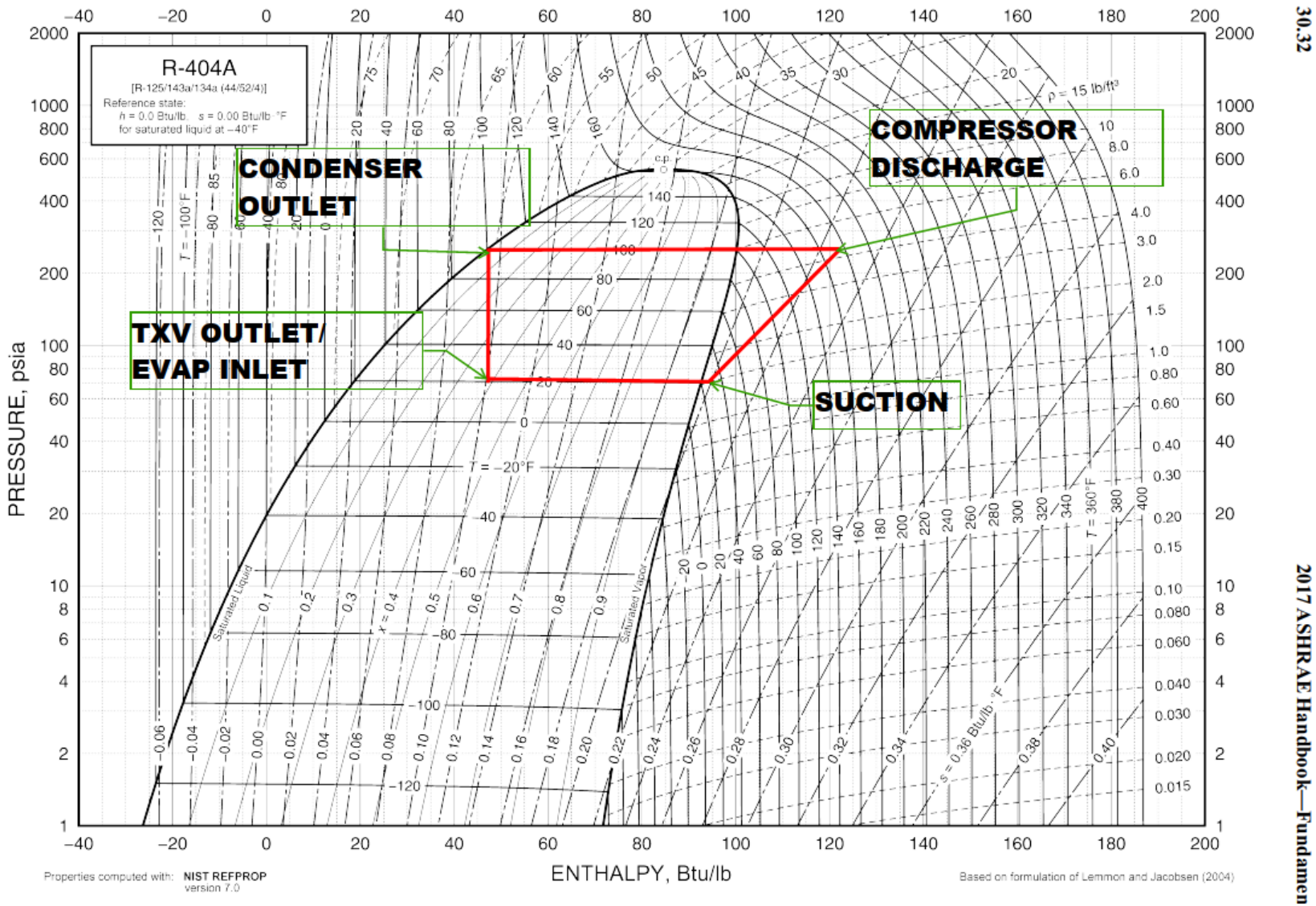


Fig. 15 Pressure-Enthalpy Diagram for Refrigerant 404A

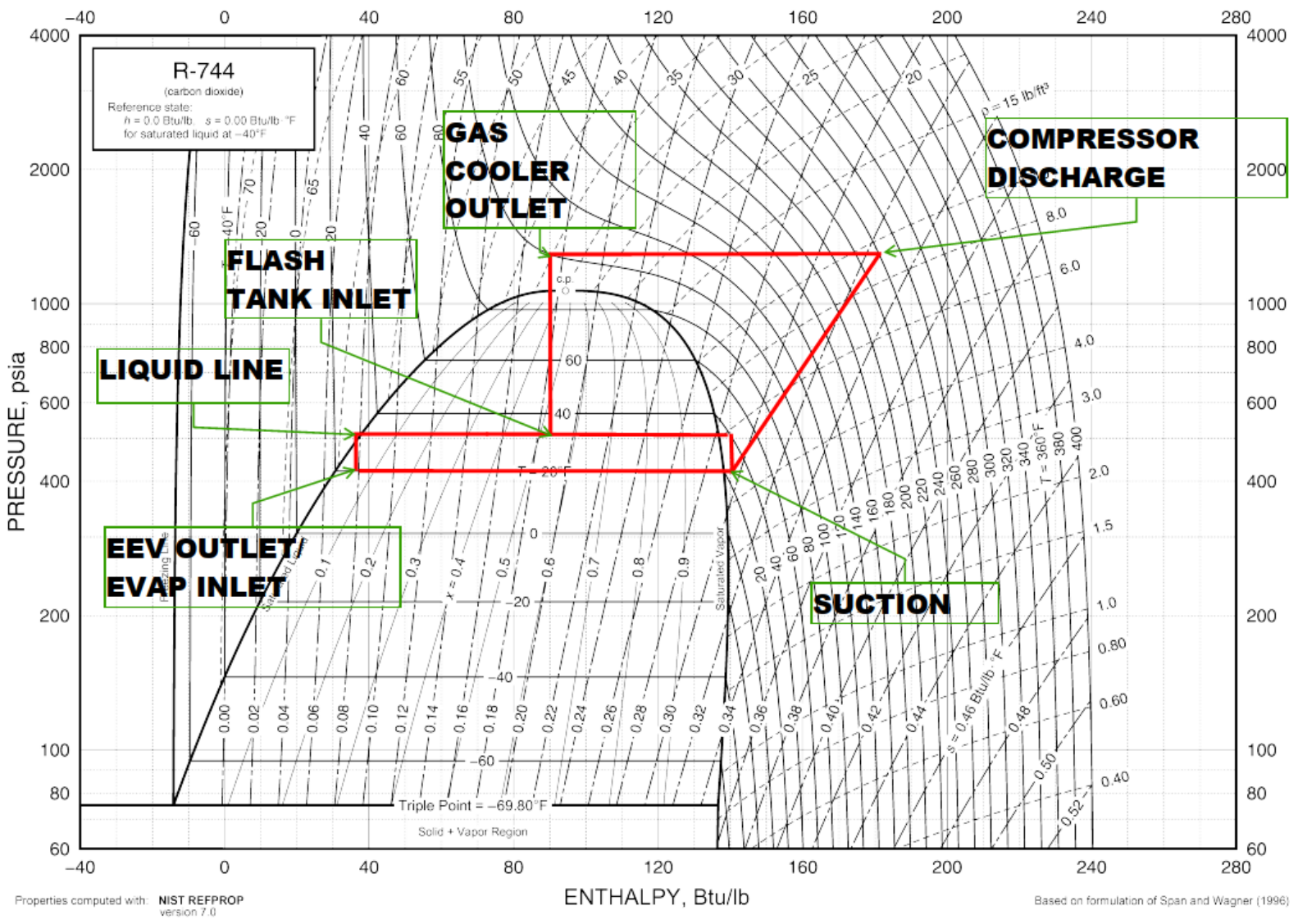
R-744 Sample PH Diagram 80F Cond, 20F SST



R-404a Sample PH Diagram 100F Cond, 20F SST

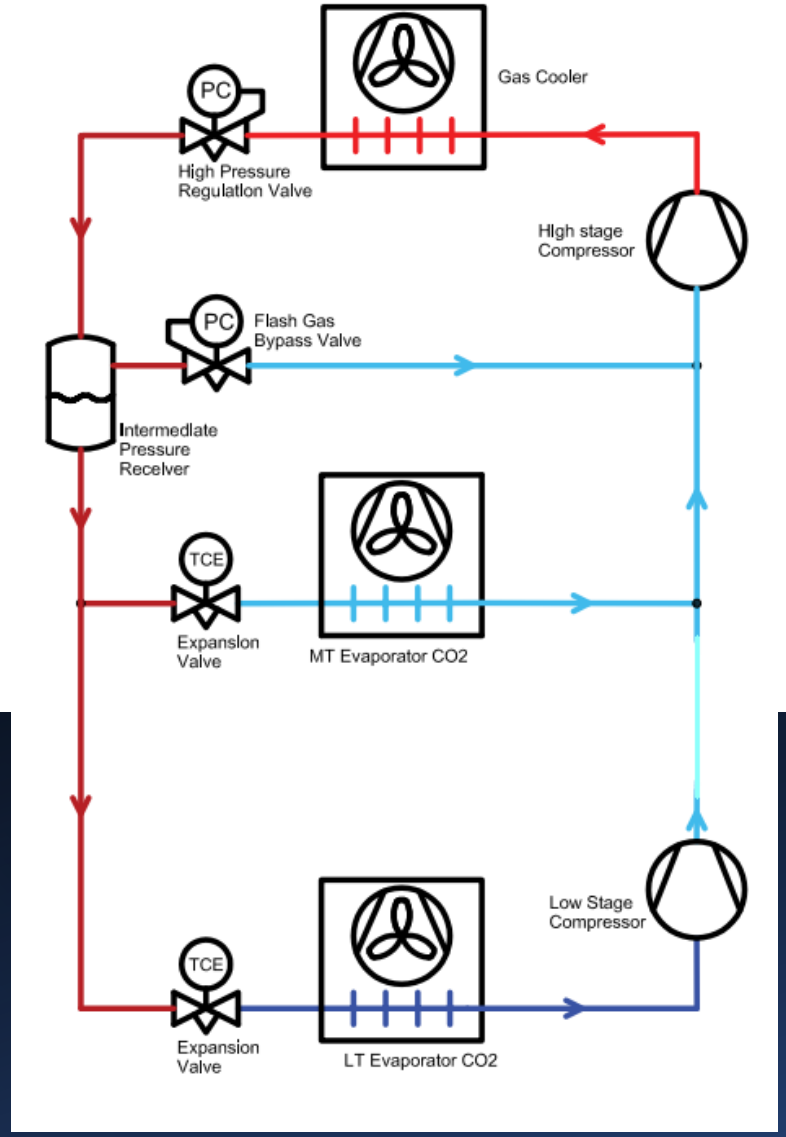


R-744 Sample PH Diagram 100F Cond, 20F SST

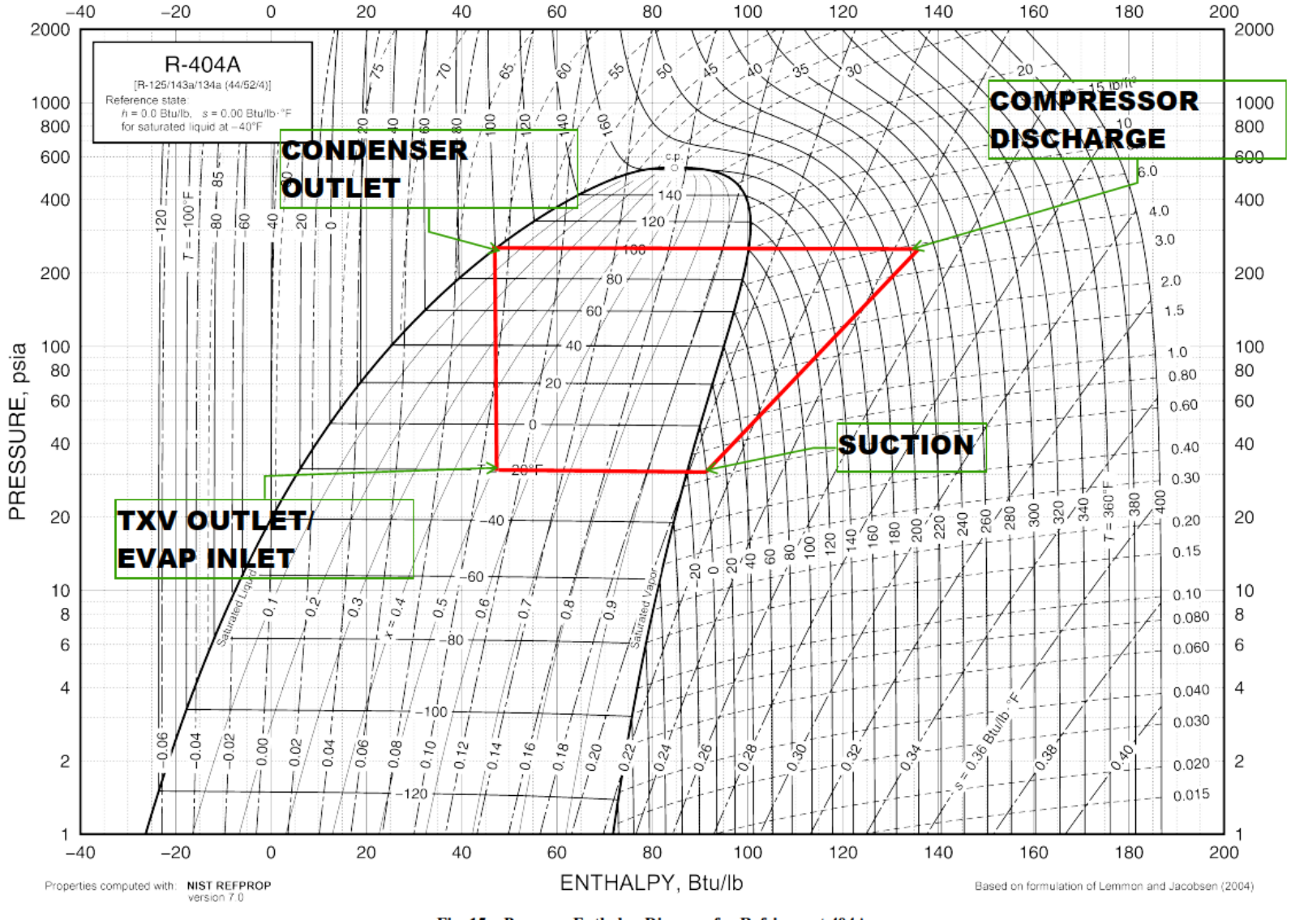


CO2 2-Stage Transcritical Design

Transcritical 2 stage 744 system architecture



R-404a Sample PH Diagram 100F Cond, -20F SST



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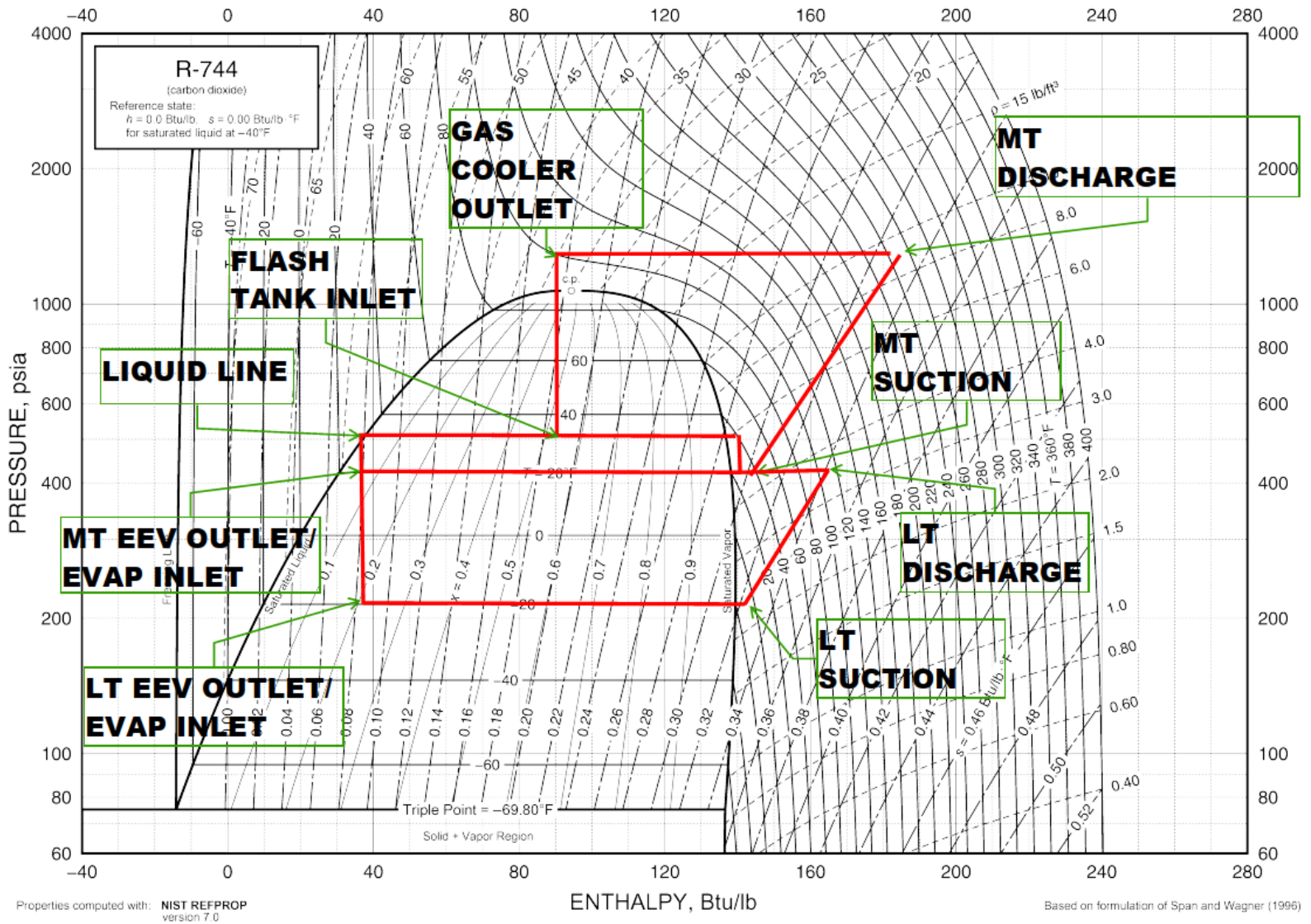
R-744 Sample PH Diagram 100F Cond, -20F SST



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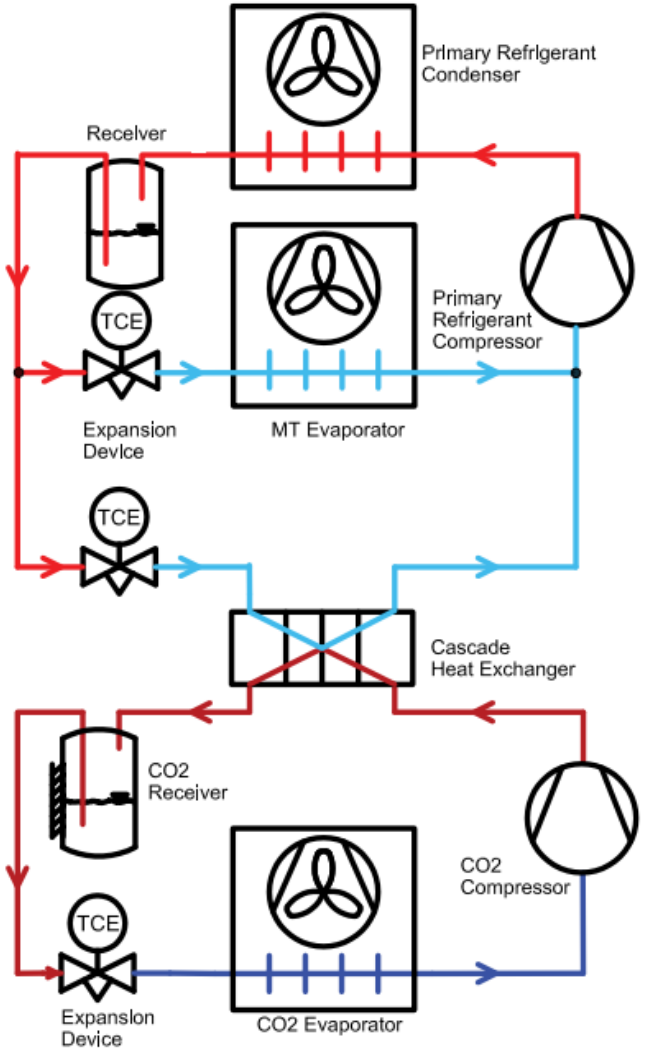
2017 ASHRAE Handbook—Fundamenta

CO2 Cascade Design

- Cascade 2 stage 744 system architecture
- High side typically close coupled, lower charge



Heat Reclaim

- High amount and quality in transcritical mode
- Typically flat plate to glycol
- High discharge pressure/density leads to high heat transfer
  - Smaller HX sizing
  - Could lead to shocking flat plates
- Temperature and pressure difference need to be accounted for in design

Oil Management

- Load between transcritical and subcritical
  - Big swing in volumetric flow
- Separator efficiency at different loads.
- Oil separator typically only on MT compressors.
- More components and piping = more spots to log oil

Oil Type

- POE: 68, 85 and 100 available
- Typically use 85
- PAG also an option
- Check with compressor/equipment manufacturer

Coalescing Separator Performance

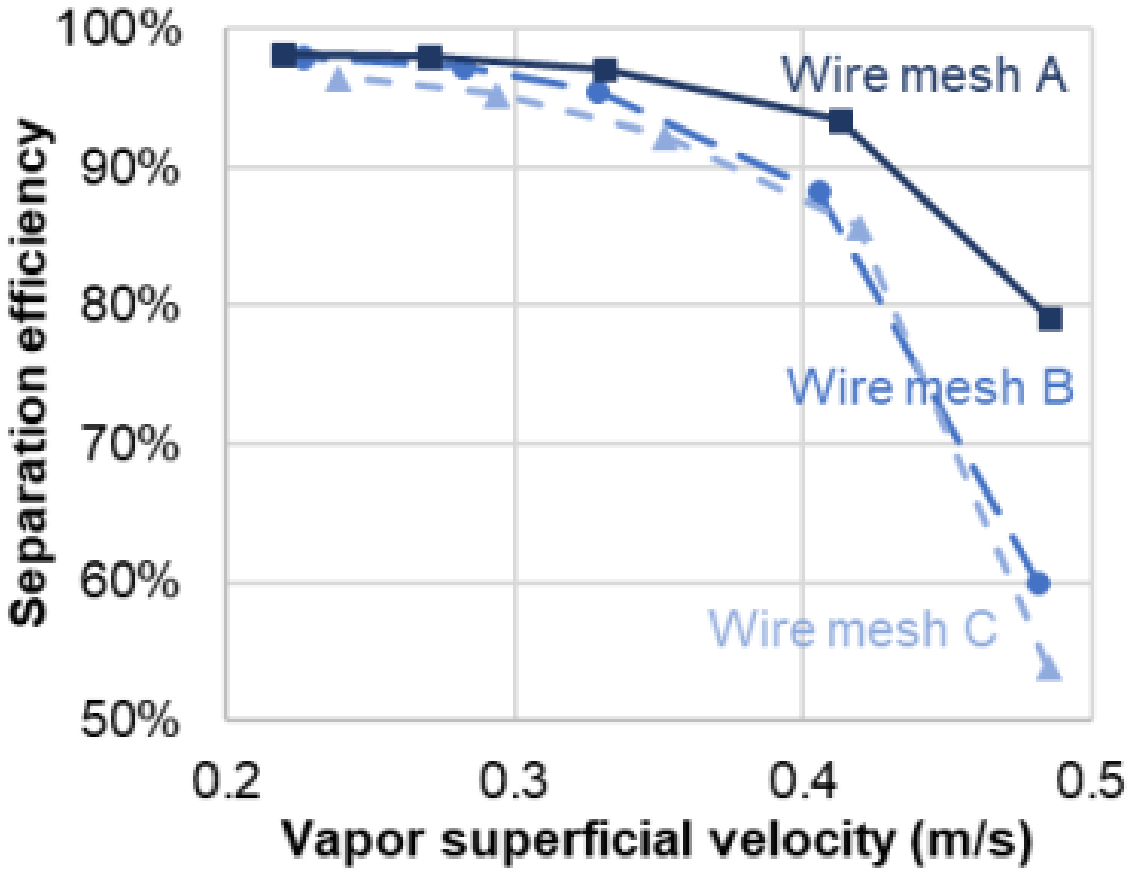
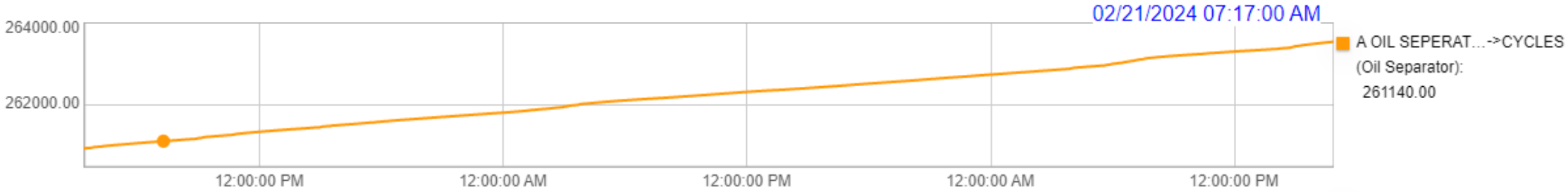


Figure 7: Separation efficiency of wire mesh pads under different working conditions

Oil Separator Cycles



Oil – Hydraulic Design

Low availability of refrigeration oil components at wholesalers rated at this pressure.

Look for other sources.

Oil Density Vs 744

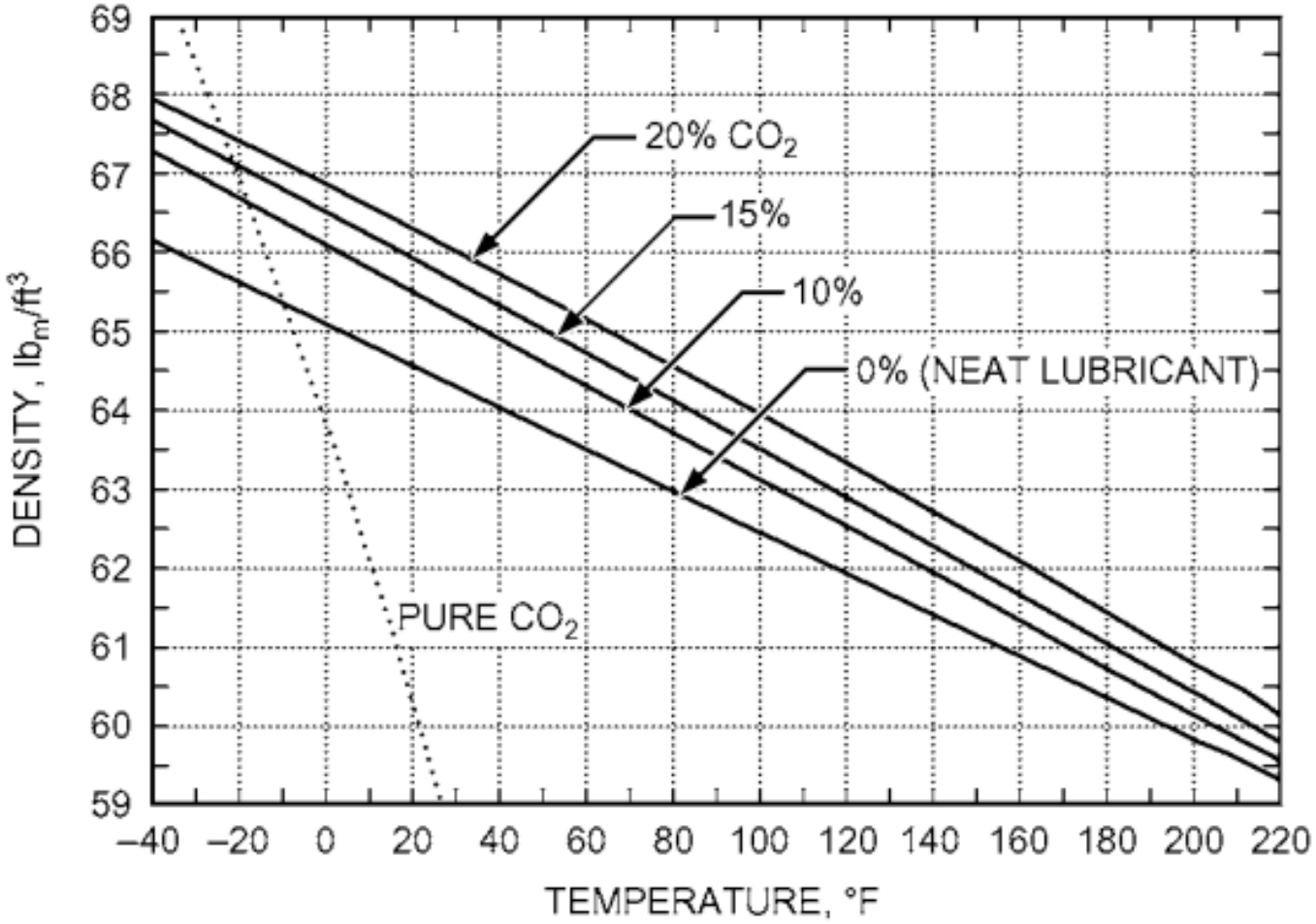


Fig. 70 Density Chart for CO_2 and ISO 55 Polyol Ester

Defrosting

- Off Cycle
- Electric
- Hot Gas
- Warm Fluid

Defrosting – Electrical

- Standard options for both commercial and industrial style evaporators/cases
- More freedom on system design
- Common Parts
- Low initial cost
- Higher energy usage

Defrosting – Hot Gas

- Options:
- Separate hot gas loop – Adds high pressure piping, additional valves, coil design more complex
- 3 or 2 pipe circuited – Adds high pressure piping, additional valves, coil design more complex, even coil defrosting
- Lower energy usage than electrical

Defrosting – Warm Fluid

- Heat reclaimed off the rack, pumped to each evaporator
- Hydronic loop with modulating valves and buffer tank
- Some standard type evaporators available
- Common Parts
- Higher initial cost
- Lower energy usage

Subcooling

- Liquid is typically at ~38F saturated
- Subcooling is needed for pressure drop in piping and heat gained from ambient
- Recommend both subcooling at rack and suction to liquid HX at evaporators
- Can have issues at startup, suction may be warmer than liquid temperature

System Controls

- Try to stick with one platform for the entire
  - Issues with communication between platforms
- Standard is to have case controller at every case and evaporator
- Leads to higher component cost but less IO boards needed
- Network cable run to evaporators instead of IO wiring

Piping

- Higher density and system design lead to smaller piping
- Higher pressure needs to be addressed
- Make sure components/piping rated for design pressure

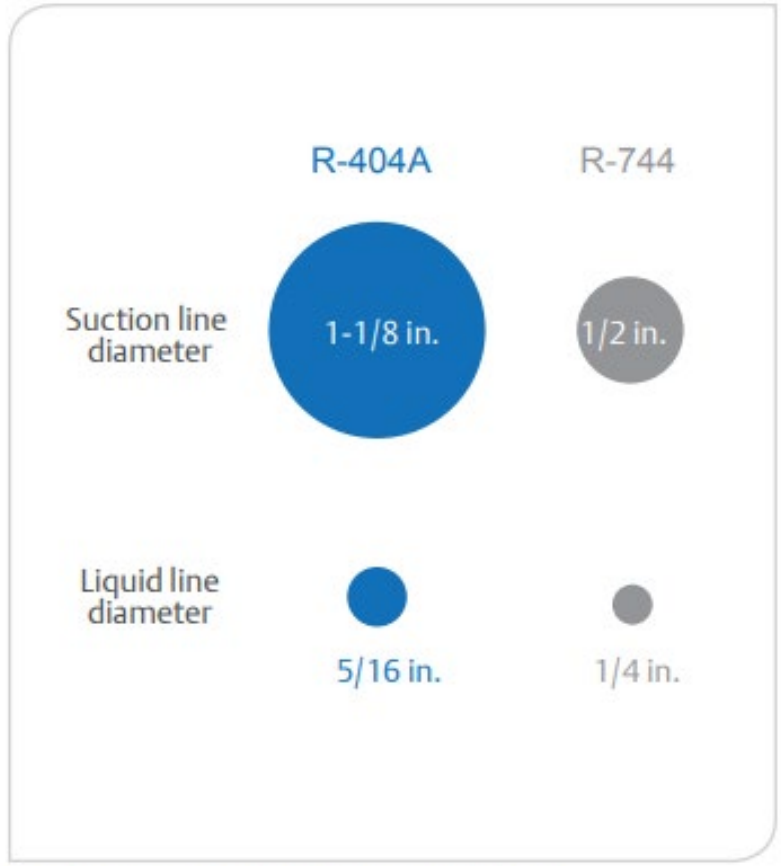


Figure 22. Comparison of pipe sizes for typical systems

Piping

Manufacturer rating for max 700psi at 250F operating conditions

Product Line	*Product Type*	*Diameter*
Copper Tube	• Refrigeration Service Coils • Line Sets & Mini-Splits • ACR - Type L (Hard Lengths) • ACR - Type K (Hard Lengths)	1/8” – 1-1/8” 1/8” – 1-1/8” 1/8” – 1-3/8” 1/8” – 2-5/8”
Copper Fittings	• Wrot Solder-Joint Pressure	1/8” – 2-5/8”

Piping Grocery Store Footage

- R-448a
- 15 Circuits Low Temp Circuit Piping 190K BTU/hr
- 27 Circuits Medium Temp Loop Piping 640K BTU/hr
- Split 50/50 Condenser

- R-744
- 15 Circuits Low Temp Loop Piping 190K BTU/hr
- 27 Circuits Medium Temp Loop Piping 640K BTU/hr
- Split 50/50 Gas Cooler

Piping Grocery Store Footage

- R-448a

Copper	FT
3/8	280
1/2	1270
5/8	3180
7/8	1145
1 1/8	2060
1 3/8	255
1 5/8	210
2 1/8	225
2 5/8	175
3 1/8	70
3 5/8	70
Total	8940

- R-774

Copper	FT
3/8	2445
1/2	1020
5/8	825
7/8	640
1 1/8	130
1 3/8	230
1 5/8	0
2 1/8	30
2 1/8 130 BAR	160

Total 5480

Other Components

- Verify pressure rating
- Relief valves and check valves need, can not entrap liquid
- Recommend adiabatic gas cooler
  - Helps reduce other issues
  - More efficient, typically short payback
- Ferrous copper – rating up to 130 BAR
- Ball valves with built in check
- Ball valves with built in drain port

Other Components

- High pressure solenoids
- EEVs – Stepper or pulse
  - Recommend solenoid in addition to stepper
- Desuperheater – standard air cooled
  - Prefer separate unit from Gas Cooler, better control

Auxiliary Condensing Unit

- Charge protection in case of power outage
- Typically, a few HP medium temp unit
- Wired to backup power
- Designed to automatically kick on based on flash tank pressure
- Maintains pressure below relief valve

Commissioning and Startup

- Do not rush startup
- Get issues resolved prior to food being put in cases
- Start medium temperature first
- Tanks are heavy 70-150 lbs for 50lbs charge
- Charging line with filter drier (good practice)
- Charge with vapor until system hits 100 psig to avoid dry ice.
- Food grade co2 in an emergency?

Notes from the field

- Outdoor vs indoor units
- Think of the service tech.
  - Hard to work on
  - Dealing with elements (rain, temps, etc.)
- Technicians need to be trained, comfortable with system
- Watch for vibrations (VFD range)
- Flash tank – watch for slag/rust/dirt/zip ties
- High amount of controls
  - Can be a benefit for diagnostic and detection

Essential components

- Things to stock
  - Refrigerant
  - Valves – HPV, FGBP
  - Oil Separator Filter
  - Controllers
- Local availability for parts
- Local service contractor when issues arise

Safety

- Prevent liquid from reaching compressor
- Dry ice.
- High pressure
- Qualified technicians
- Trapped liquid
- Pressure relief valves
- Leak detection
- False alarms from dry ice in cases

	R-744	HFC / HCFC	Impact on R-744 Systems
Global Warming Potential	1	1300 to 4000	Future Proof
Ozone Depleting Potential	0	0 for HFC / High for HCFC	Future Proof
Saturation Pressures	Higher	Lower	Additional Safety Design
Operating Pressures	Higher	Lower	Specialized Components
Standstill Pressures	Higher	Lower	Relief Valves/Tanks/ etc..
(Power Outages)	Rapid Pressure Rise	Lower	Pressure Relief Venting
Inert Gas	Yes	Yes	Copper may be used
Flammability	A1	A1	Not Flammable
Toxicity	No	No	Asphyxiate in High Concentrations
Odor	None	None	Leak Detection Required
Volumetric Mass Flow	Higher	Lower	Smaller Tubes & Compressors
Heat Transfer	Higher	Lower	Better Thermal Efficiency
High Ambient Performance	Lower	Higher	System Design to Compensate
Low Ambient Performance	Good	Good	Subcritical Cascade Favorable
Cost per Pound	Low	Higher	Economical
Complexity of Systems	Higher	Lower	Higher First Cost, Training & Experience
Adoption	Low	Higher	Higher First Cost
Legislation / Regulations	Low	Higher	Long-Term Viability

744 vs HFC Recap

Recap

Regulations driving the change.

Upfront design a good idea.

Learn from prior installs.

Bibliography

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Questions?