AIRAH – Refrigeration (in HVAC) Back to Basics

For the First Time

Terms of Reference

What this session is NOT about

- Detailed Refrigeration Design
- Detailed analysis of various Refrigants properties
- Comparison of Natural v Synthetics
- Comparison of Oil-free v Oiled
- Energy analysis
- Component Selections
- **Teaching any of us to be an “Expert”**

Terms of Reference

What this session IS about

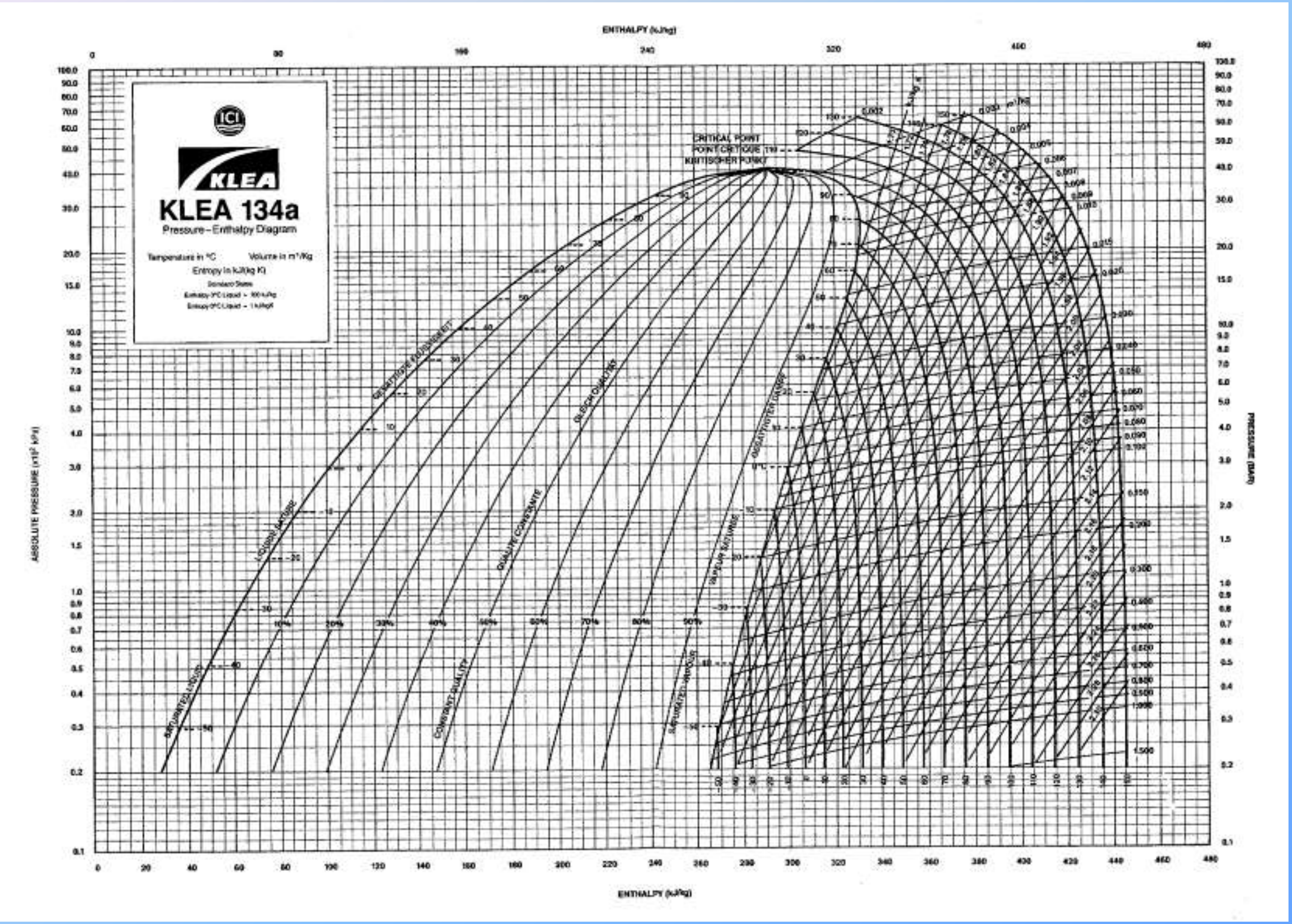
- Introduction to Refrig SYSTEM basics
- Basic understanding
- For “Beginners” or “occasional” designers
- HVAC context really
- How to know WHEN to seek HELP
- How not to Shoot one’s own foot.

Who Talks

- Everyone
- Including Ben, Craig and Mike …

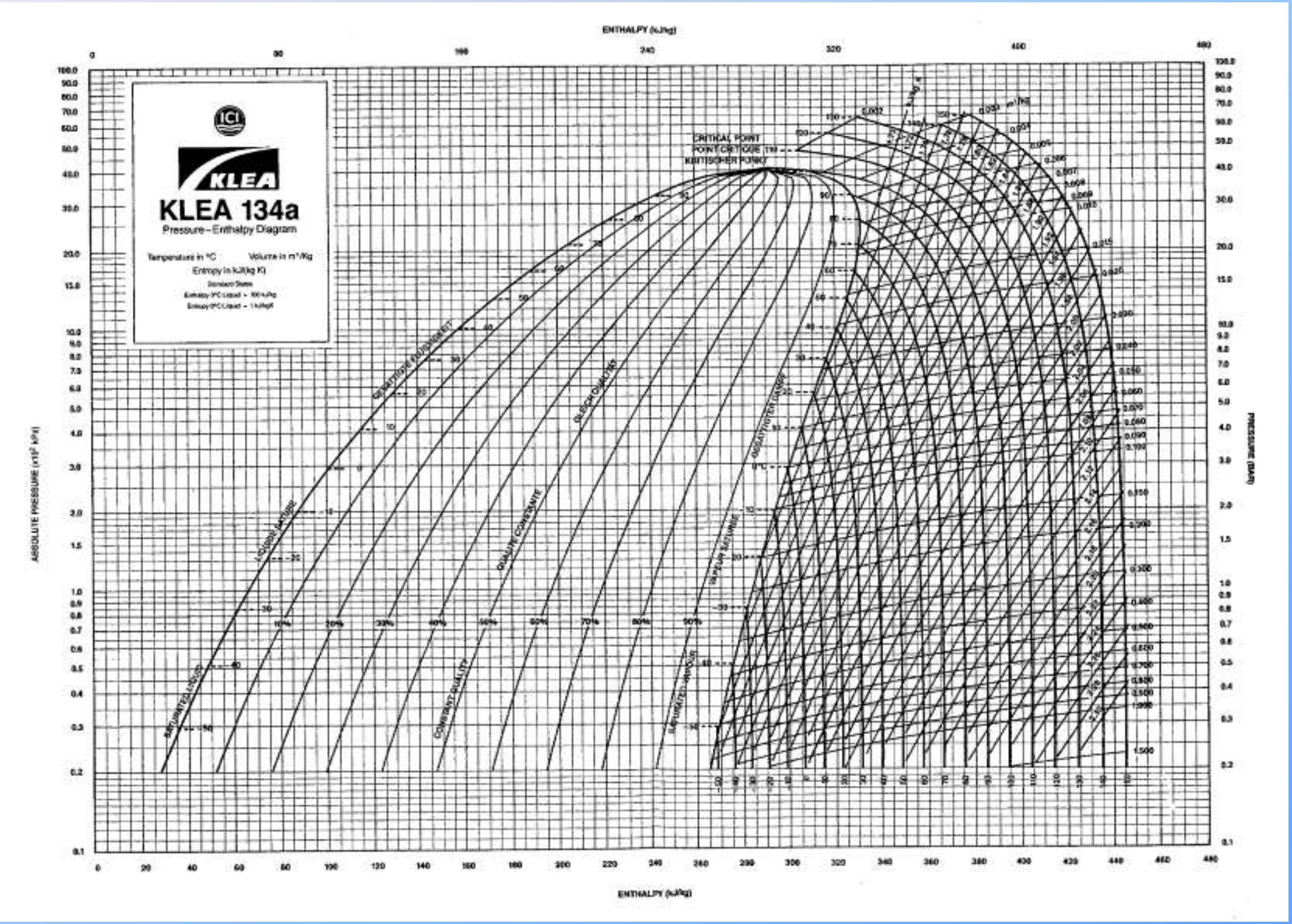
(This is a Discussion forum, not a lecture)

It's a …….

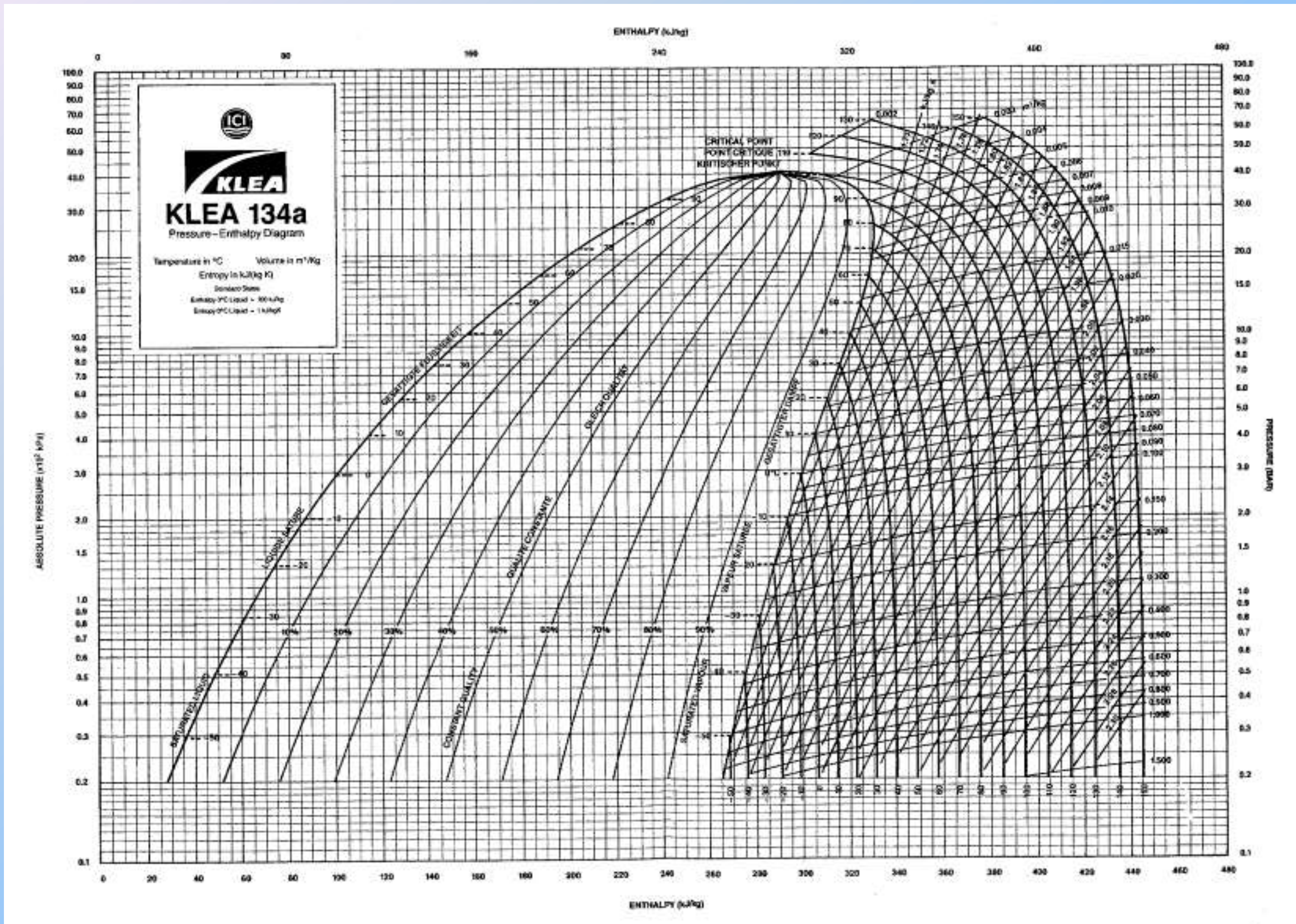


ENTHALPY (kJ/kg)
KLEA
KLEA 134a
Pressure–Enthalpy Diagram
Temperature in °C
Volume in m³/Kg
Entropy in kJ/(kg K)
CRITICAL POINT
POINT CRITIQUE
KRITISCHER PUNKT
ABSOLUTE PRESSURE (x10² kPa)
PRESSURE (BAR)
10%
20%
30%
40%
50%
60%
70%
80%
90%
SATURATED LIQUID
SATURATED VAPOUR
CONSTANT QUALITY

Pressure Enthalpy Chart



It’s important because ?



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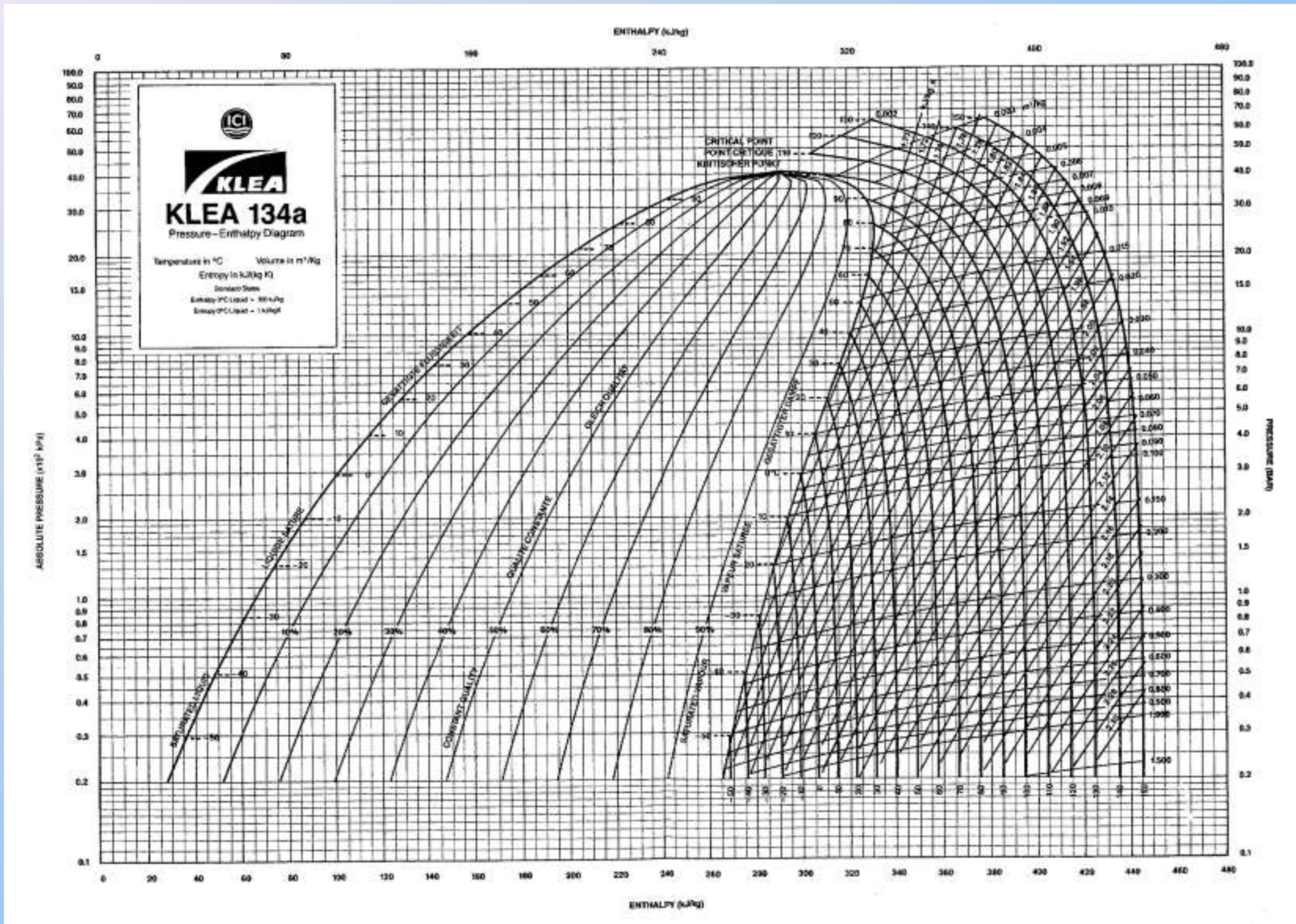
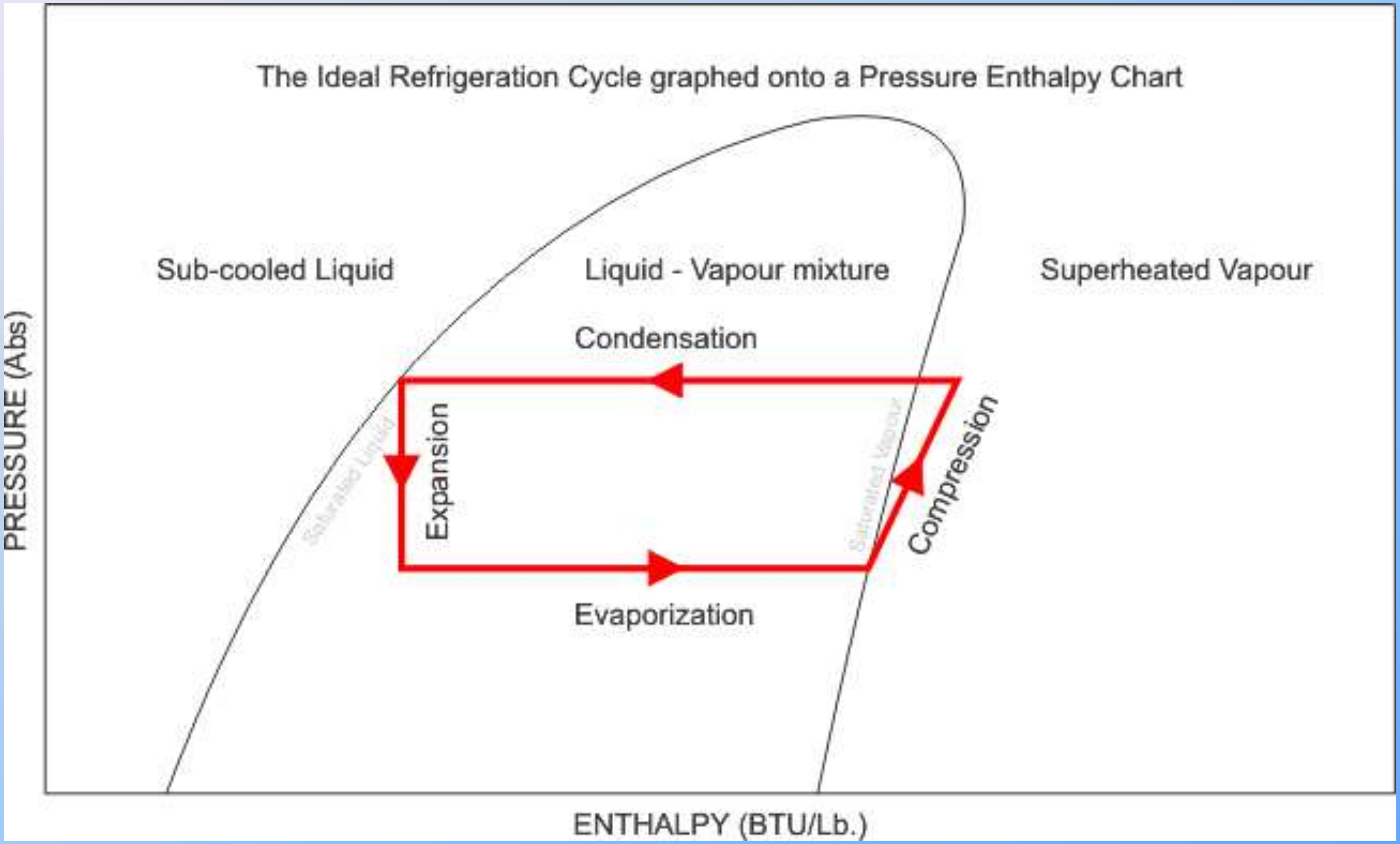
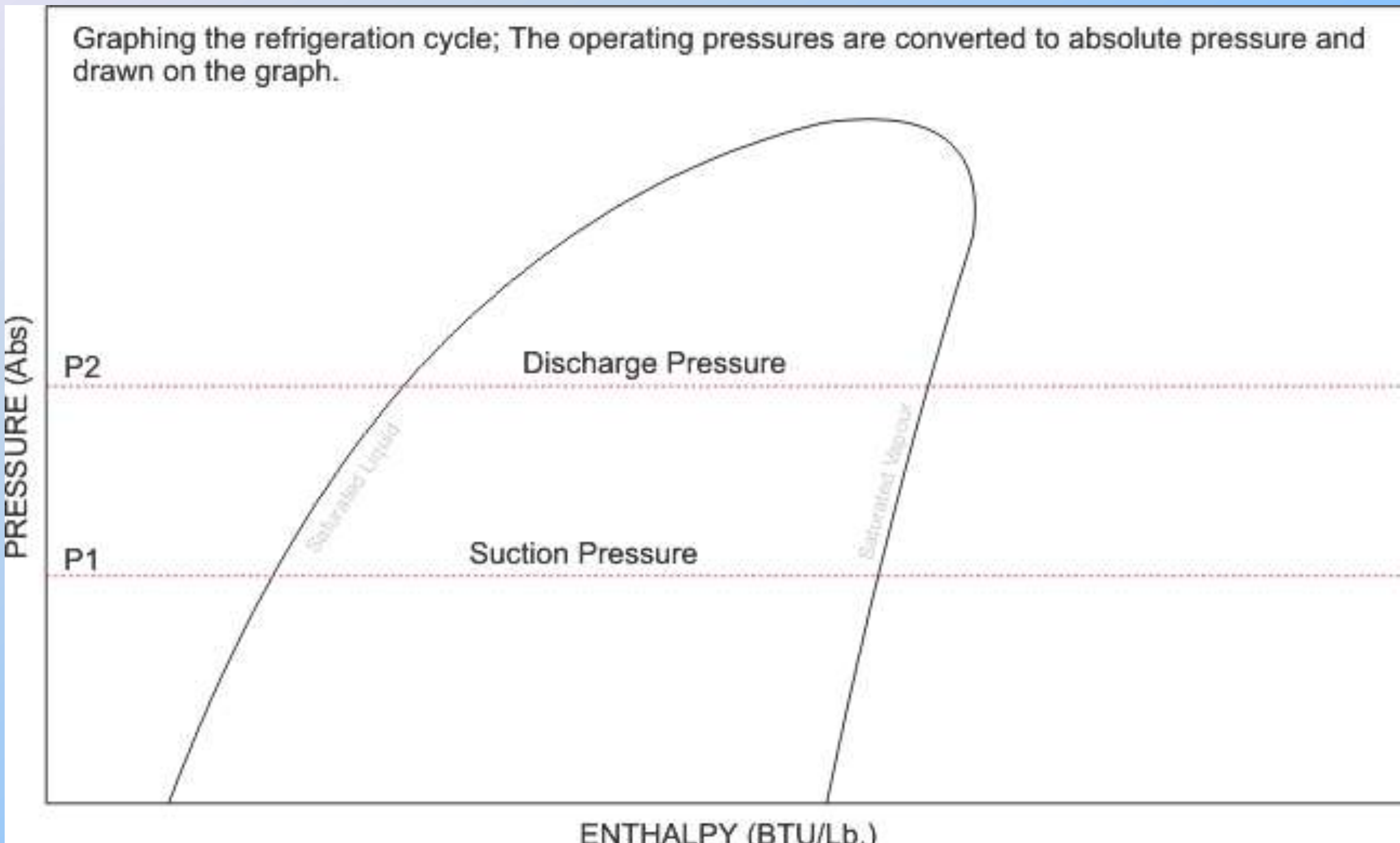


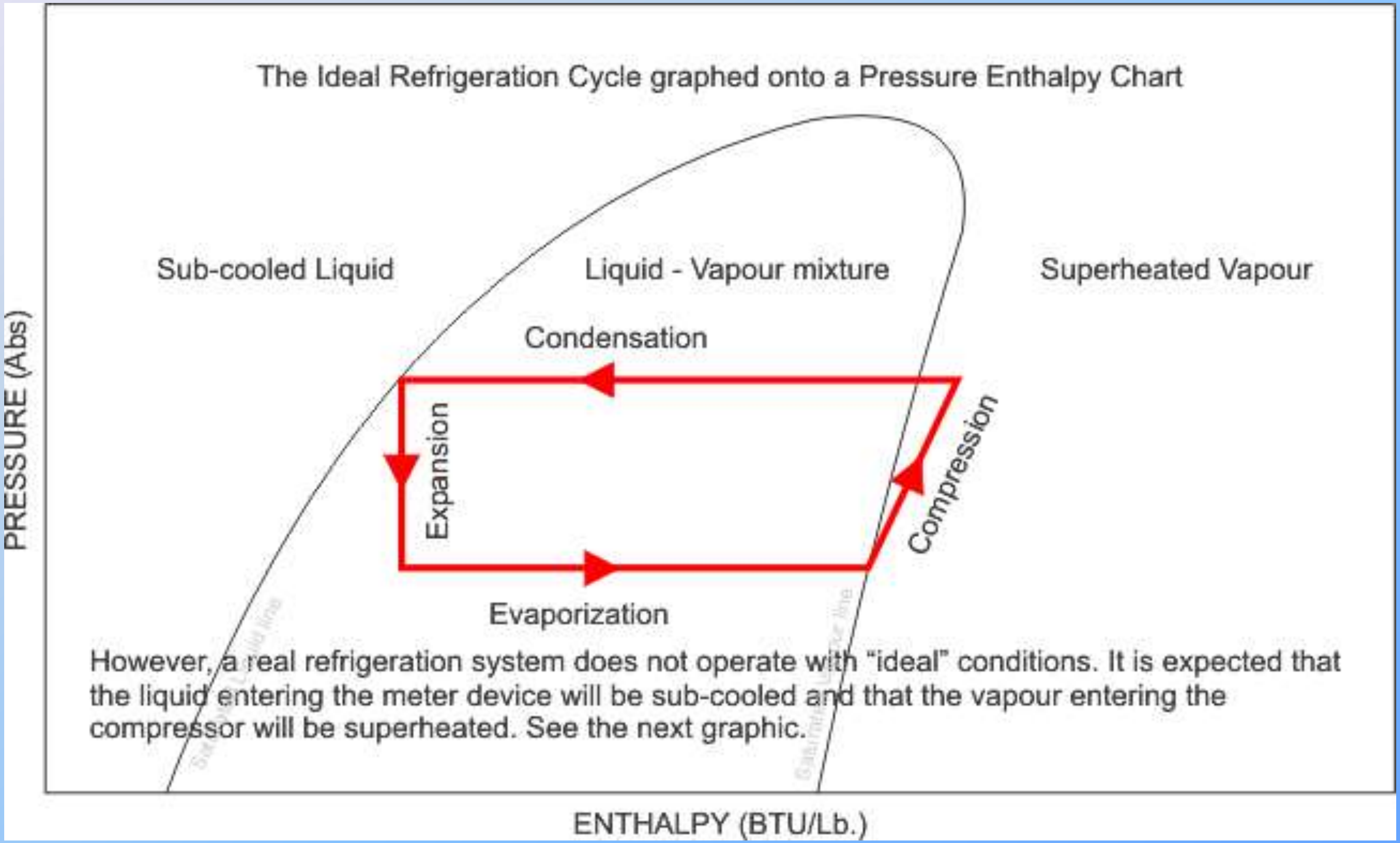
What it looks like in theory



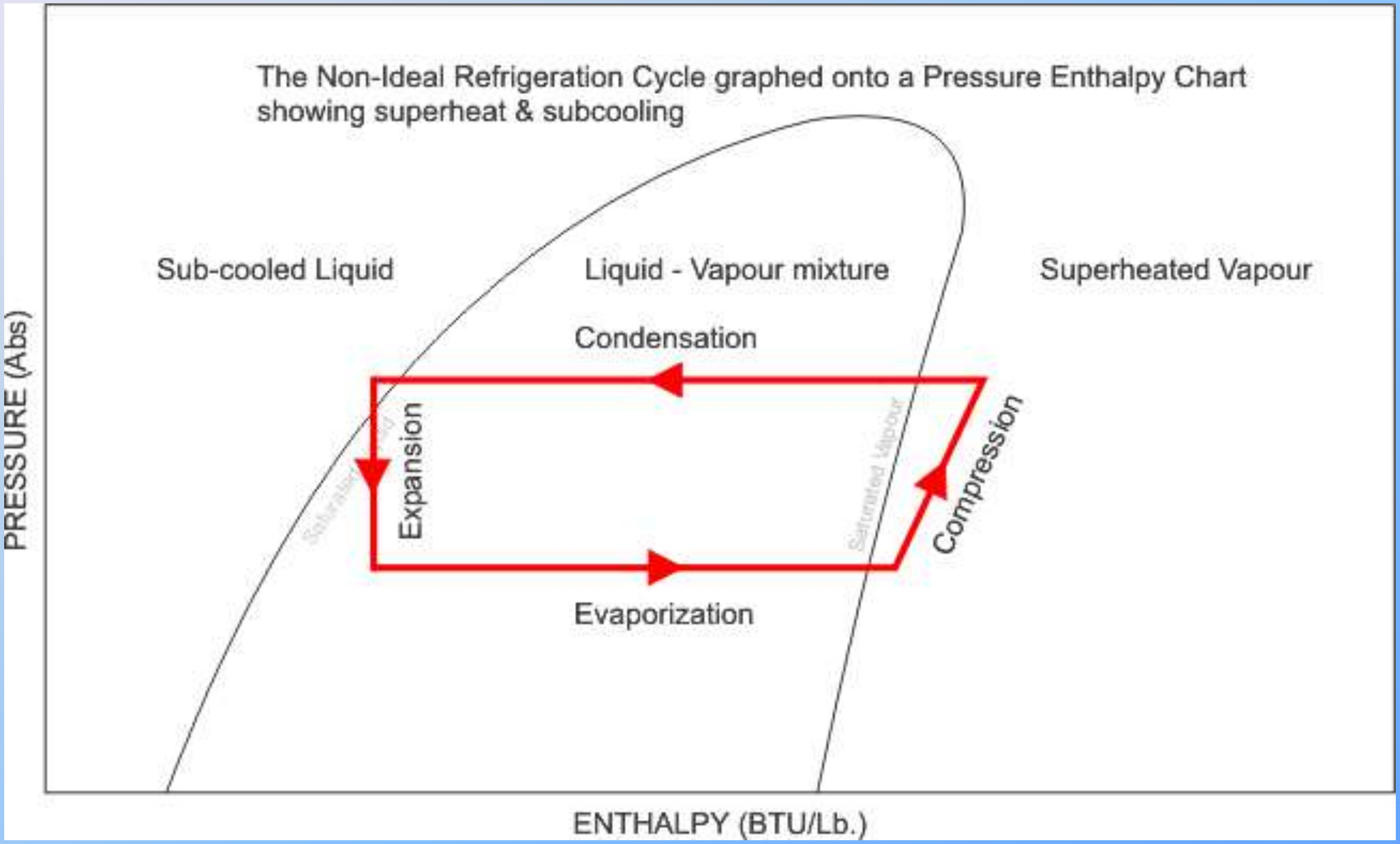
It's a Compressor … it has…



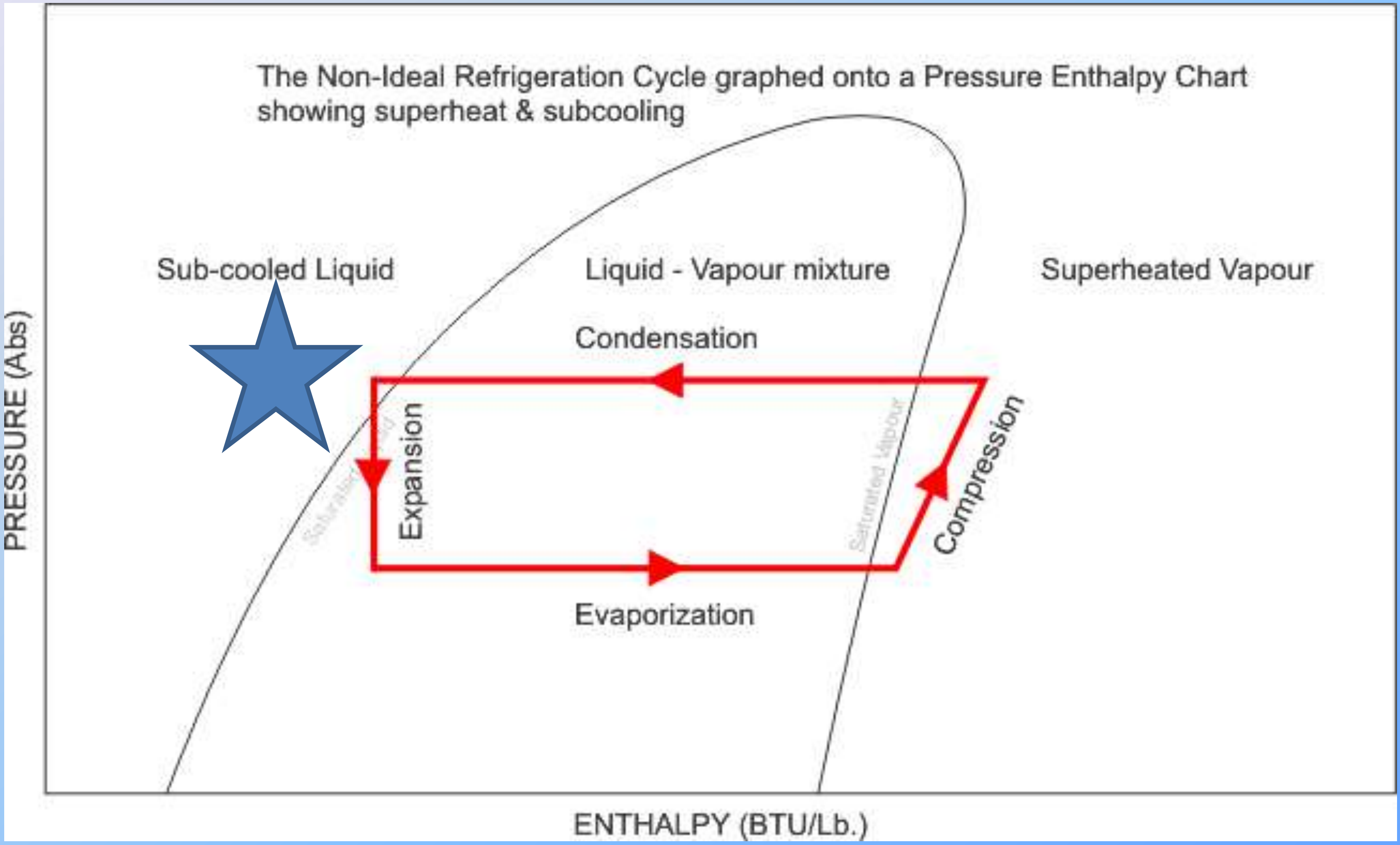
And then the Refrigerant flows



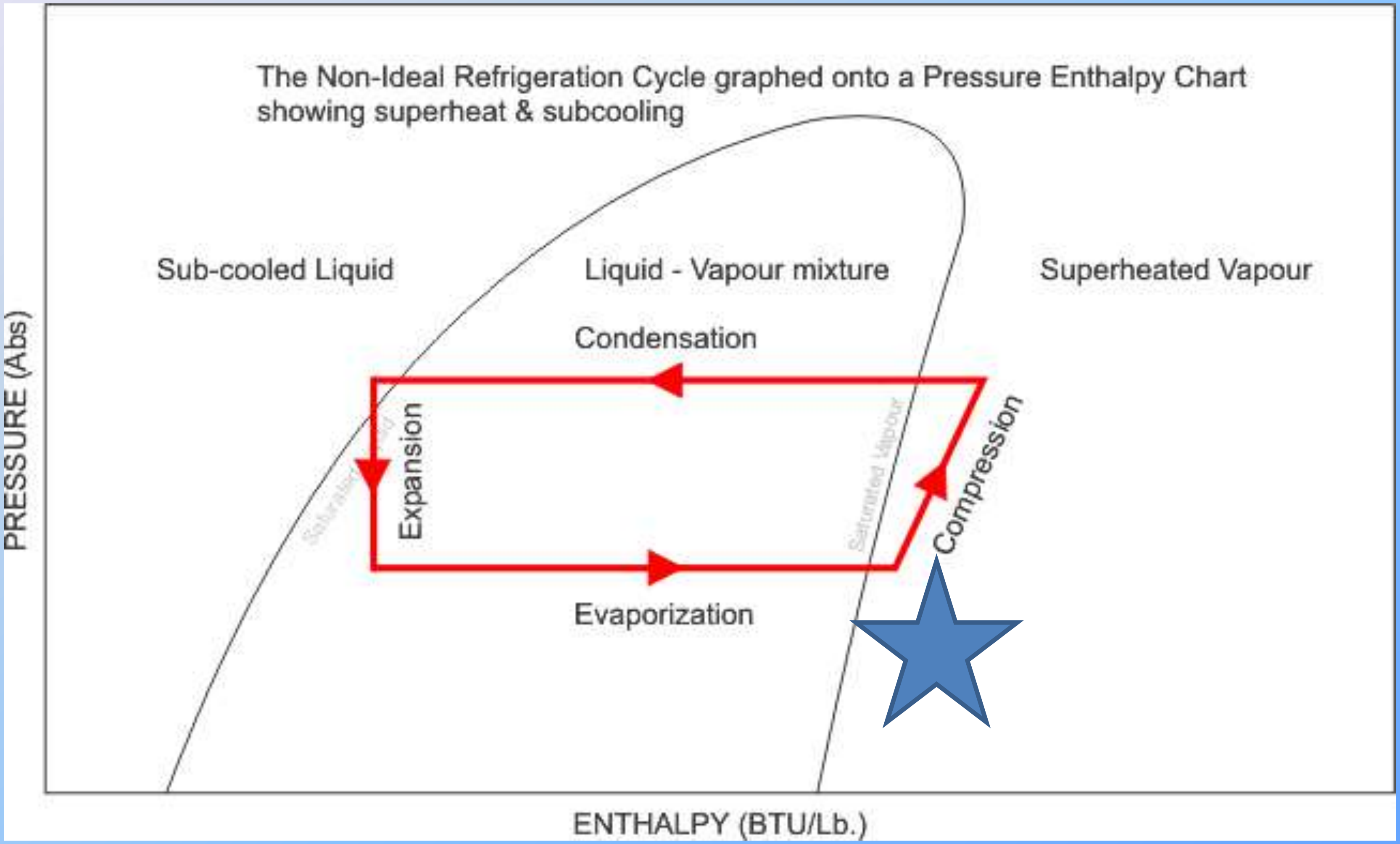
But really the Chart looks a little more like this



What is subcooling and why do we need it



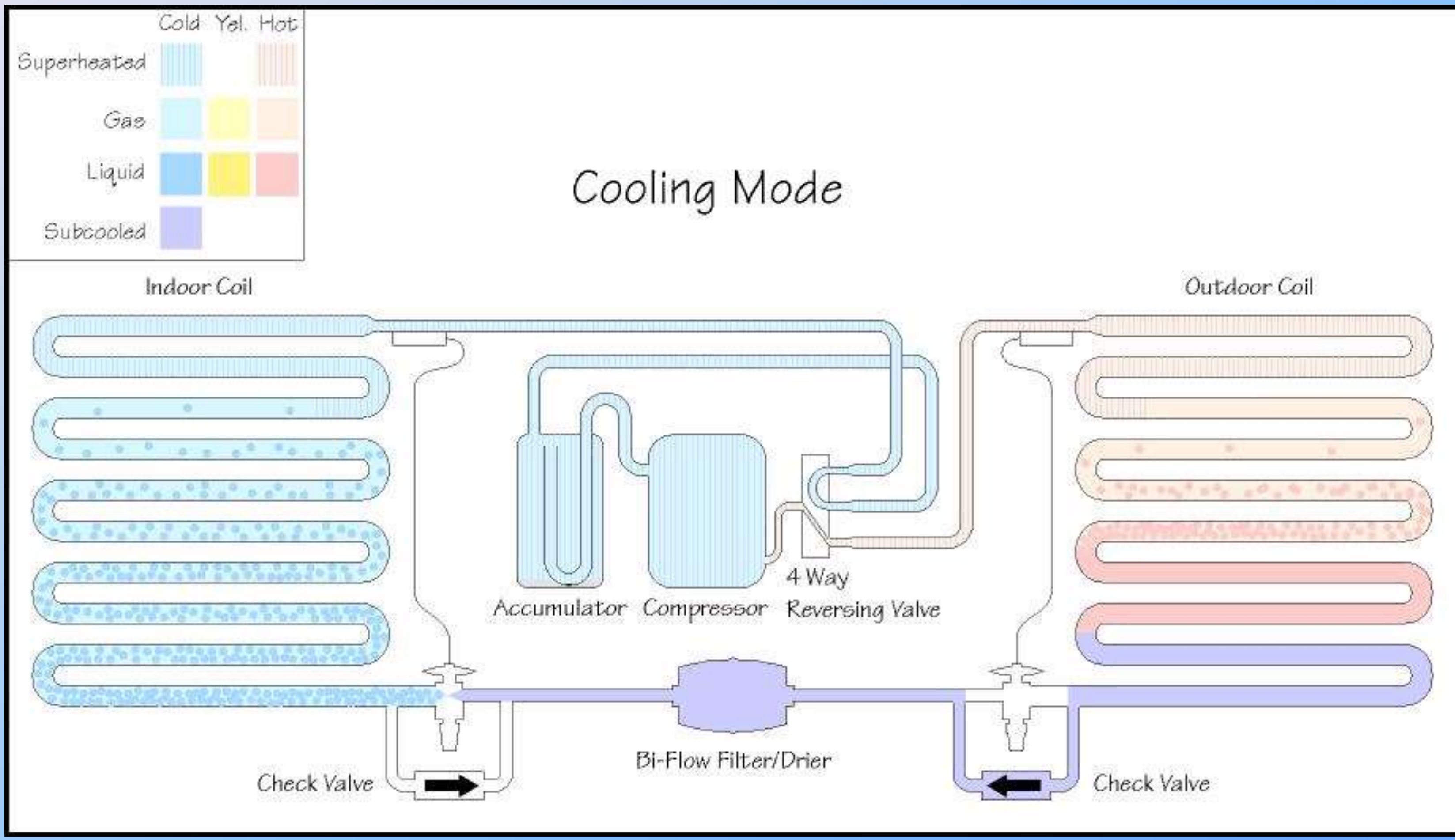
What is Superheat and why do we want it?



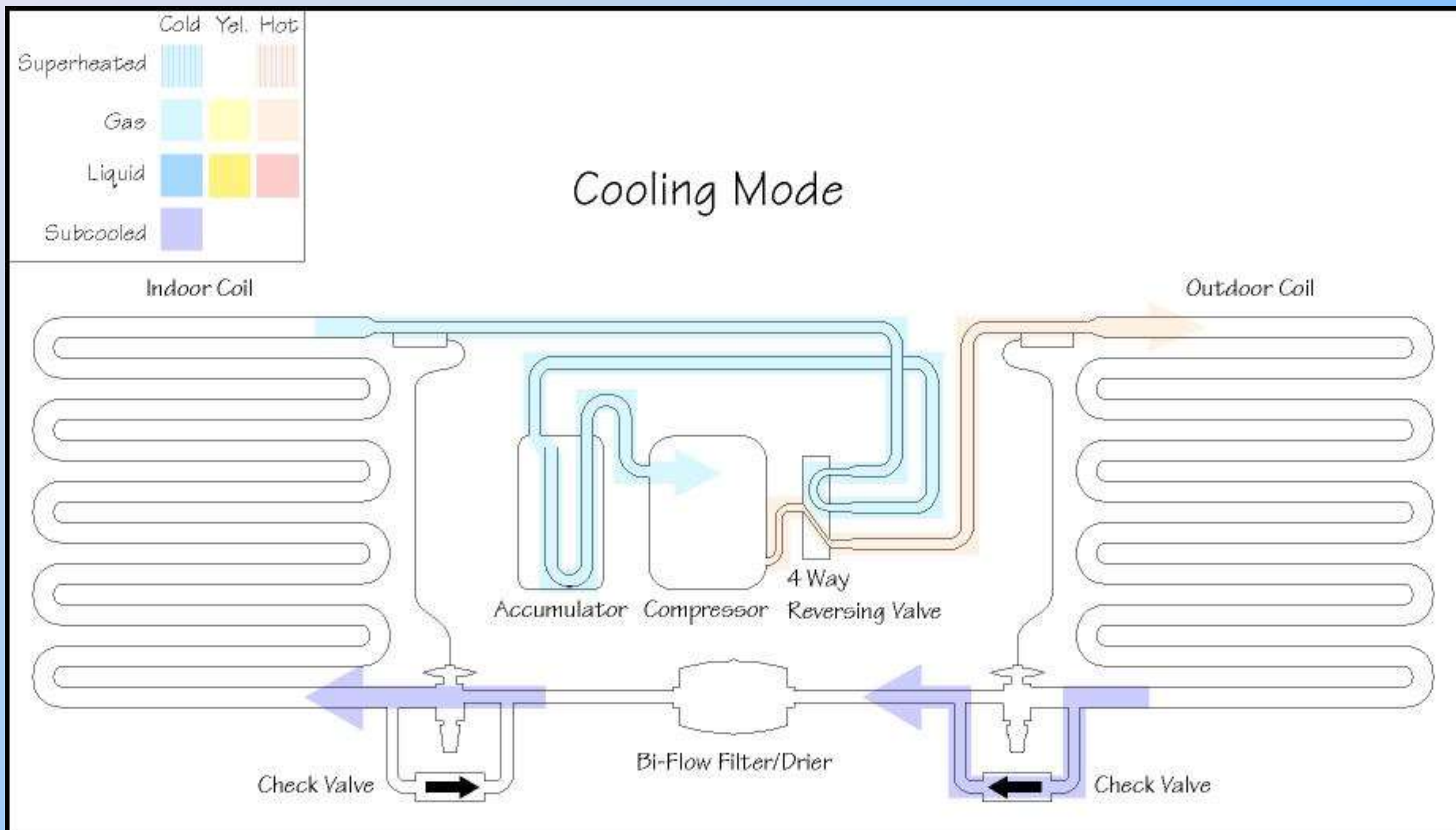
Some compressors

Some other bits

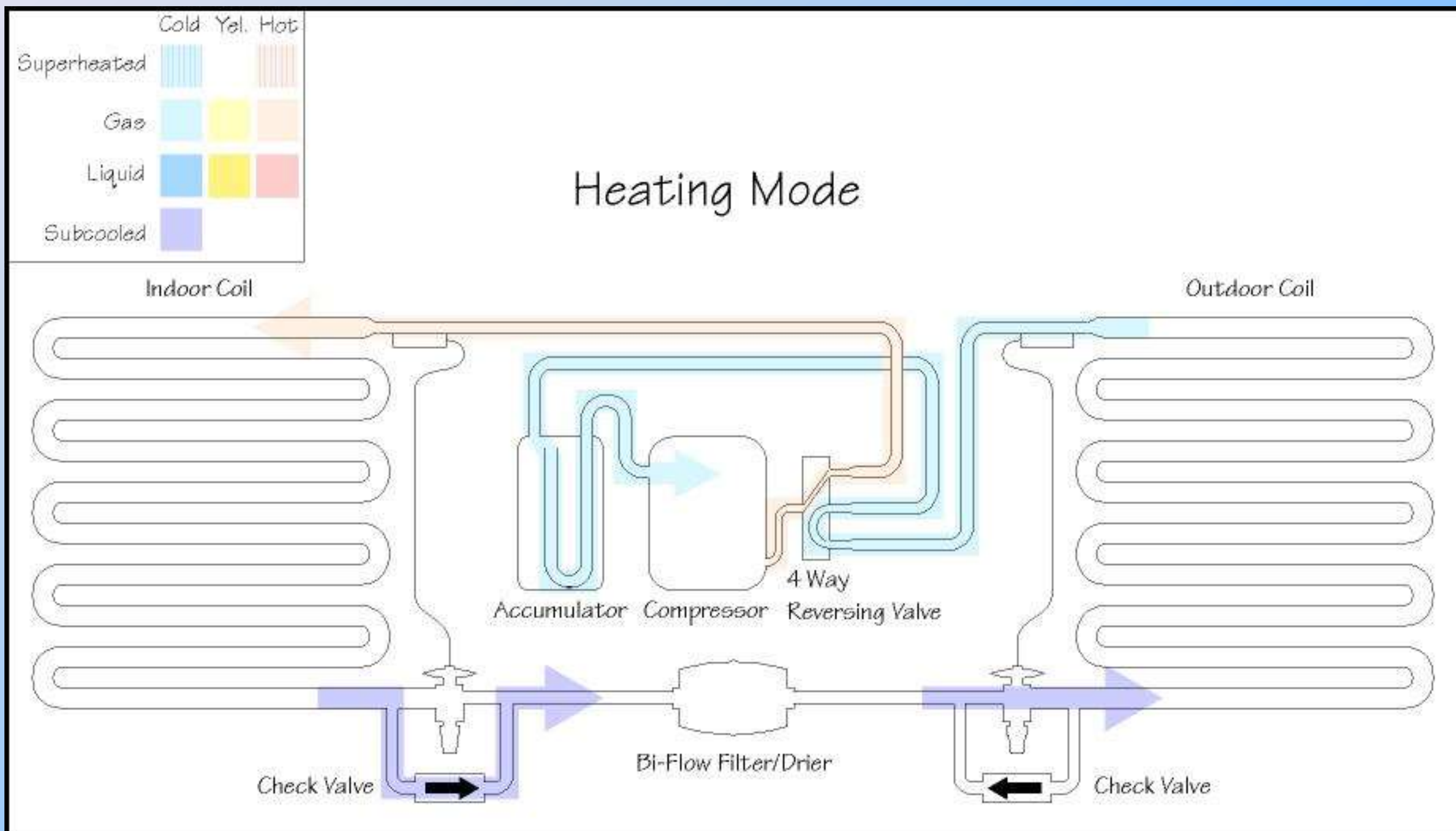
And when we turn it into a PACKAGE it looks like this



PACKAGE forwards



PACKAGE reverse



Compressors

Apart from Absorption Chillers, evaporative cooling and other specialised systems, ***most refrig cycle applications = vapour compression.***

- Reciprocating
- Scroll
- Screw
- Centrifugal

OIL

- What purpose does oil serve (primarily)
- What components does it lubricate
- How can it move in a closed system
  - Gravity
    What goes up ….
  - Refrigerant Absorption
    At any normal temperature, the vapour pressure of the oil in a refrigeration system is much lower than the vapour pressure of the refrigerant, and during shut down periods, as a result of the miscibility of refrigerant in oil, refrigerant in contact with the surface of an oil pool is absorbed into the oil.
  - Oil pump-out
    Oil pump-out can occur when sufficient foam is delivered into the system by the compressor at start-up so as to reduce the oil content in the sump to a level too low for effective supply to the compressor's oil pump.

REFRIG SYSTEM

A properly designed and installed refrigerant piping system should:

- Provide adequate refrigerant flow to the evaporators, using practical refrigerant line sizes that limit pressure drop
- Avoid trapping excessive oil so that the compressor has enough oil to operate properly at all times
- Avoid liquid refrigerant slugging
- Be clean and dry

What happens if the oil is where it should not be

System fully charged with refrigerant and oil – so how does a bearing go Dry and WELD?

Foaming.
Oil exclusion.
Oil return failure

AKA how to make many parts into ONE

What happens if the oil is where it should not be

Floodback or slugging –

Liquid IN the compressor –

be it liquid refrigerant or oil

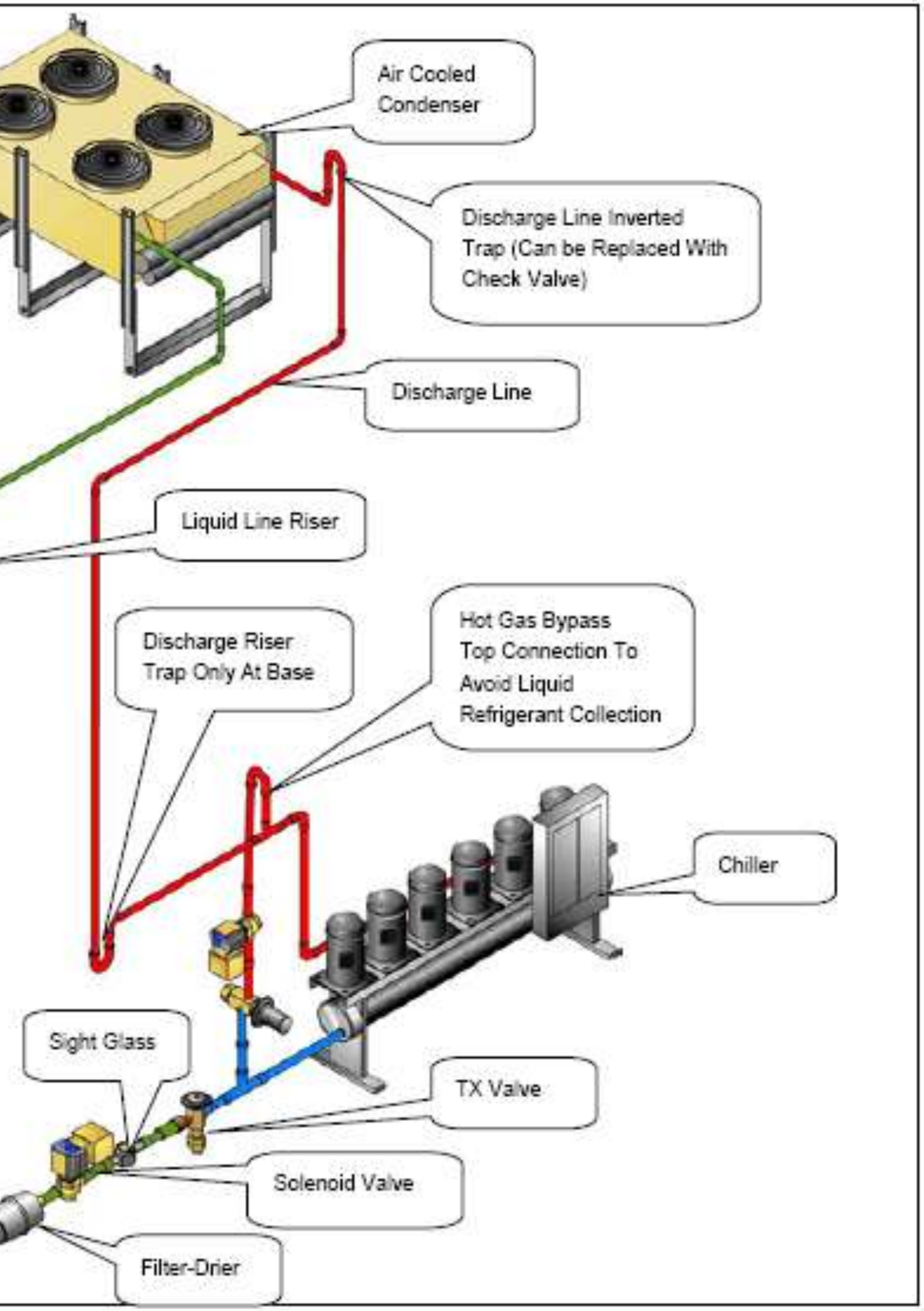
AKA how to make ONE part into MANY

REFRIG PIPING SYSTEM

A properly designed and installed refrigerant piping system should:

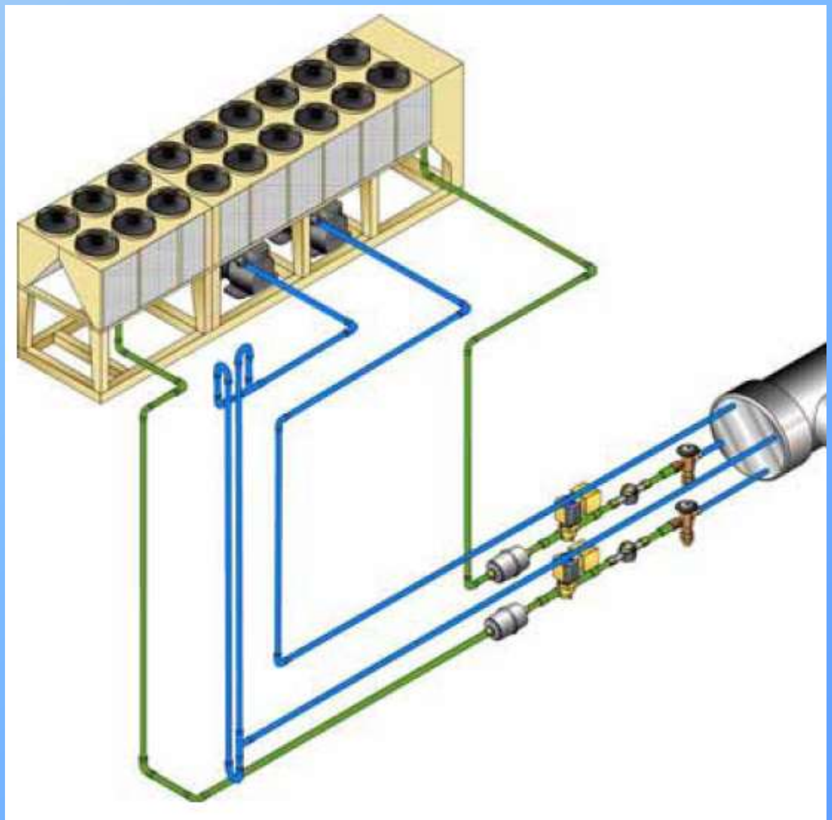
- Provide **adequate refrigerant flow to the evaporators**, using practical refrigerant line sizes that limit pressure drop
- **Avoid trapping excessive oil** so that the compressor has enough oil to operate properly at all times
- Avoid liquid refrigerant **slugging**
- **Be clean and dry**

McQuay Application Guide AG31-011

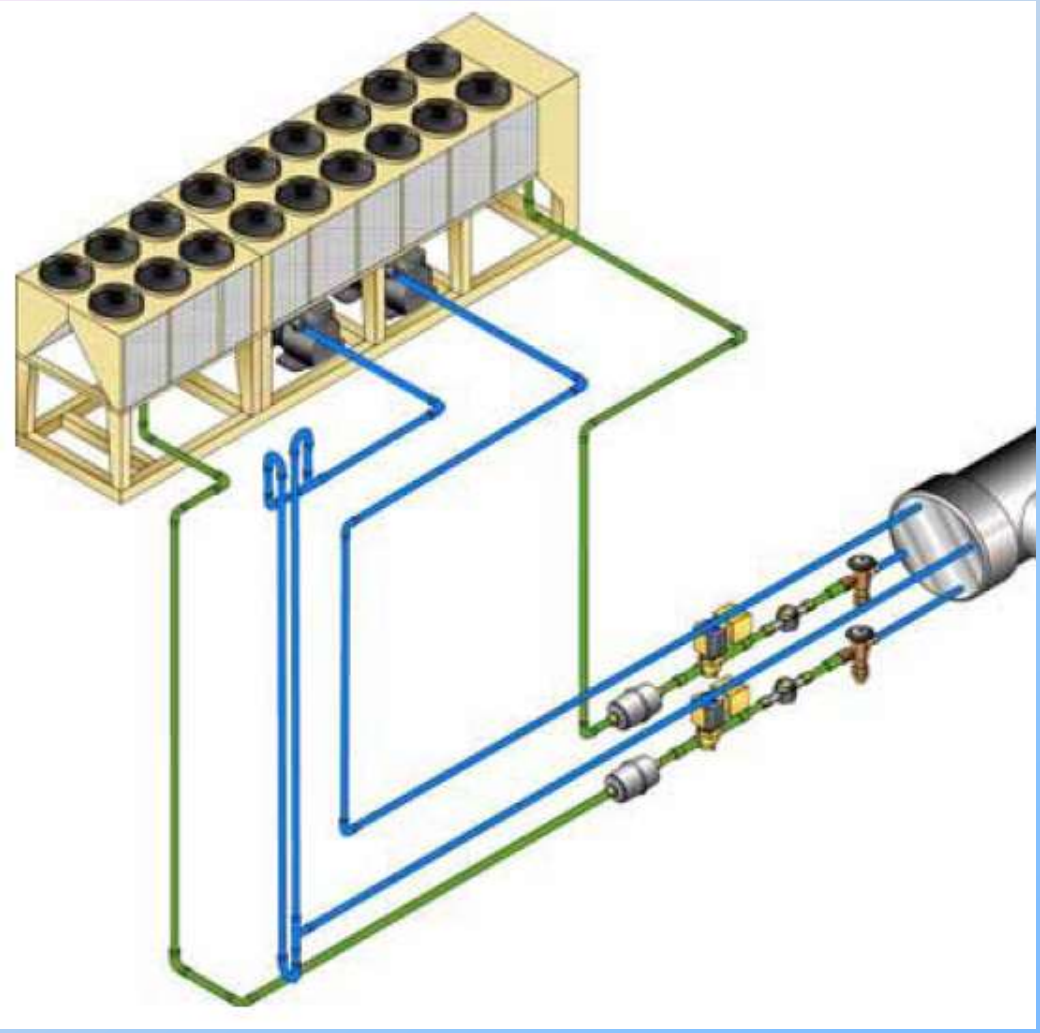


REFRIG SYSTEM

- Traps in Discharge line for this arrangement
- Where are the traps in the suction line?
- Hot gas mixing line…
- All falls to traps…



REFRIG SYSTEM



- Traps in Suction line for this arrangement
- Why are there two?
- All falls to traps…

Heat Rejection

- Remember the p-e chart –
  Total Heat of rejection
- Rejection to Air is dominated by Dry Bulb temperature
- Rejection to Water is dominated by the water body temperature or by the approach to Wet-Bulb.
- Wet Bulb is always “colder” than dry bulb

What does a suction line have to do

- Suction gas lines allow refrigerant **gas** from the evaporator to flow into the inlet of the compressor.
- Undersizing the suction line reduces compressor capacity by forcing it to operate at a lower suction pressure to maintain the desired evaporator temperature.
- Oversizing the suction line increases initial project costs and **may result in insufficient refrigerant gas velocity to move oil from the evaporator** to the compressor.
- This is particularly important when vertical suction risers are used.

Basic sizing of a suction line

- Suction lines should be sized for a maximum of 2 to 3°F (1.1 to 1.7°C) pressure loss.
- The actual pressure drop in kPa will depend on the refrigerant.
- Fall:
  Suction lines should continously fall in the direction of flow – 10mm/m minimum
- Gas Velocity needs to return oil to the compressor **even at low load**
- Velocity > 750 fpm in horizontal, 1500fpm in vertical
  3.8m/s **7.6m/s**

Use the CHART

- But then calculate pressure drop for your system
- Check velocity for oil return

Table 34 - R-134a Refrigerant Line Size Table (kW)[21]

	Suction									Discharge			Liquid	
SST	0°C			5°C			10°C			-10°C	0°C	10°C		
ΔT (K/m)	0.04	0.02	0.01	0.04	0.02	0.01	0.04	0.02	0.01	0.02	0.02	0.02	vel = 0.5 m/s	0.02
Δp (Pa/m)	425	212	106	487	243	121	555	278	136	538	538	538		538
OD (mm)														
12	0.92	0.63	0.43	1.11	0.76	0.51	1.33	0.91	0.62	1.69	1.77	1.84	6.51	8.50
15	1.76	1.20	0.82	2.12	1.45	0.99	2.54	1.74	1.19	3.23	3.37	3.51	10.6	16.30
18	3.60	2.09	1.43	3.69	2.53	1.72	4.42	3.03	2.07	5.61	5.86	6.09	16.0	28.40
22	5.40	3.69	2.52	6.50	4.46	3.04	7.77	5.34	3.66	9.87	10.3	10.7	24.5	50.1
28	10.7	7.31	5.01	12.8	8.81	6.02	15.3	10.6	7.24	19.5	20.3	21.1	41.0	99.6
35	19.6	13.4	9.21	23.5	16.2	11.1	28.1	19.4	13.3	35.6	37.2	38.7	64.9	183.0
42	32.4	22.3	15.3	39.0	26.9	18.4	46.5	32.1	22.1	59.0	61.6	64.1	95.2	304.0
54	64.4	44.4	30.5	77.3	53.4	36.7	92.2	63.8	44.0	117.0	122.0	127.0	160.0	605.0
67	115.0	79.0	54.4	138.0	95.0	65.4	164.0	113.0	78.3	208.0	217.0	225.0	248.0	1080.0
79	177.0	122.0	84.3	213.0	147.0	101.0	253.0	176.0	122.0	321.0	335.0	349.0	346.0	1670.0
105	379.0	262.0	181.0	454.0	315.0	217.0	541.0	375.0	260.0	686.0	715.0	744.0	618.0	3580.0

Values in Table 34 are based on 40°C condensing temperature. Multiply table capacities by the following factors for other condensing temperatures.

Condensing Temperature (°C)	Suction Line	Discharge Line
20	1.239	0.682
30	1.120	0.856
40	1.0	1.0
50	0.888	1.110

Notes for Table 34:

1. Table Capacities are in kilowatts of refrigeration.
2. Δp = pressure drop per unit equivalent length of line, Pa/m
3. Δt = corresponding change in saturation temperature, K/m
4. Line capacity for other saturation temperatures Δt and equivalent lengths L_e

$$Line\ Capacity = Table\ Capacity\left(\frac{Table\ L_e}{Acutal\ L_e} \times \frac{Actual\ \Delta t}{Table\ \Delta t}\right)^{0.55}$$

5. Saturation temperatures ΔT for other capacities and equivalent lengths L_e

$$\Delta t = Table\ \Delta t\left(\frac{Actual\ L_e}{Table\ L_e}\right)\left(\frac{Actual\ Capacity}{Table\ Capacity}\right)^{1.8}$$

How do you get the gas velocity?

Figure 22 - R-134a Suction Gas Velocity

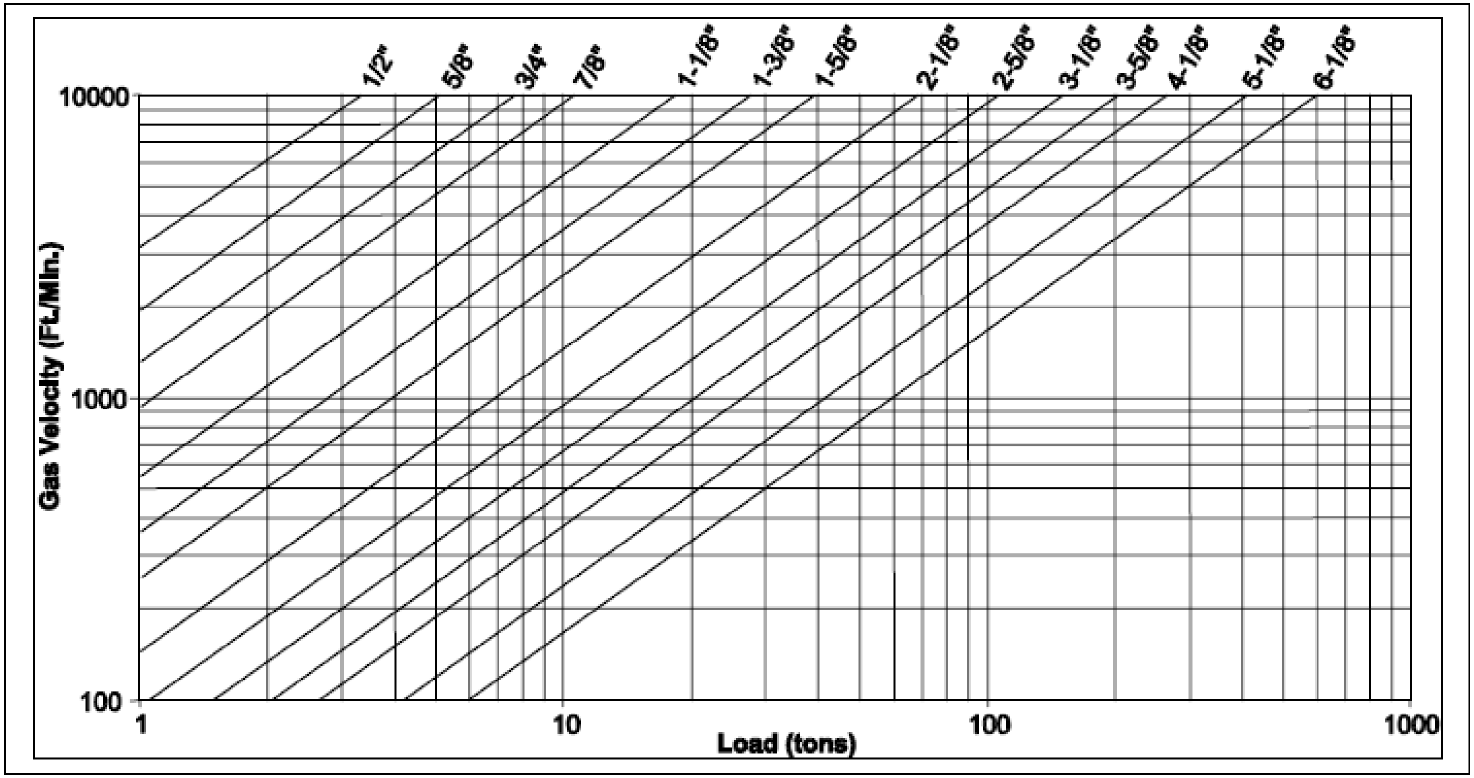


Figure 22 is based on 40°F Suction temperature and 105°F condensing temperature. For other conditions, apply correction factors from Table 23.

What does a discharge line have to do

- Discharge gas lines (often referred to as hot gas lines) allow refrigerant to flow from the discharge of the compressor to the inlet of the condenser.
- Undersizing discharge lines will reduce compressor capacity and increase compressor work.
- Over sizing discharge lines increases the initial cost of the project and may result in insufficient refrigerant gas velocity to carry oil back to the compressor.
- Discharge lines should be sized for no more than 2 to 3°F (1.1 to 1.7°C) pressure loss.
- The actual pressure drop in PSI will depend upon the refrigerant.
- Capacity and power consumption are affected by increasing pressure drop for both discharge and suction lines.

- *SOUND FAMILIAR ?*

- **must prevent oil trapping at minimum capacity**
- **must prevent backflow of oil or refrigerant to the compressor during low load or shutdown**

Basic sizing of a discharge line

- …. Surprise ….

Use the CHART

- But then calculate pressure drop for your system
- Check velocity for oil return

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28	10.7	7.31	5.01	12.8	8.81	6.02	15.3	10.6	7.24	19.5	20.3	21.1	41.0	99.5
35	19.6	13.4	9.21	23.5	16.2	11.1	28.1	19.4	13.3	35.6	37.2	38.7	64.9	183.0
42	32.4	22.3	15.3	39.0	26.9	18.4	46.5	32.1	22.1	59.0	61.6	64.1	95.2	304.0
54	64.4	44.4	30.5	77.3	53.4	36.7	92.2	63.8	44.0	117.0	122.0	127.0	160.0	605.0
67	115.0	79.0	54.4	138.0	95.0	65.4	164.0	113.0	78.3	208.0	217.0	225.0	248.0	1080.0
79	177.0	122.0	84.3	213.0	147.0	101.0	253.0	176.0	122.0	321.0	335.0	349.0	346.0	1670.0
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What does a liquid line have to do

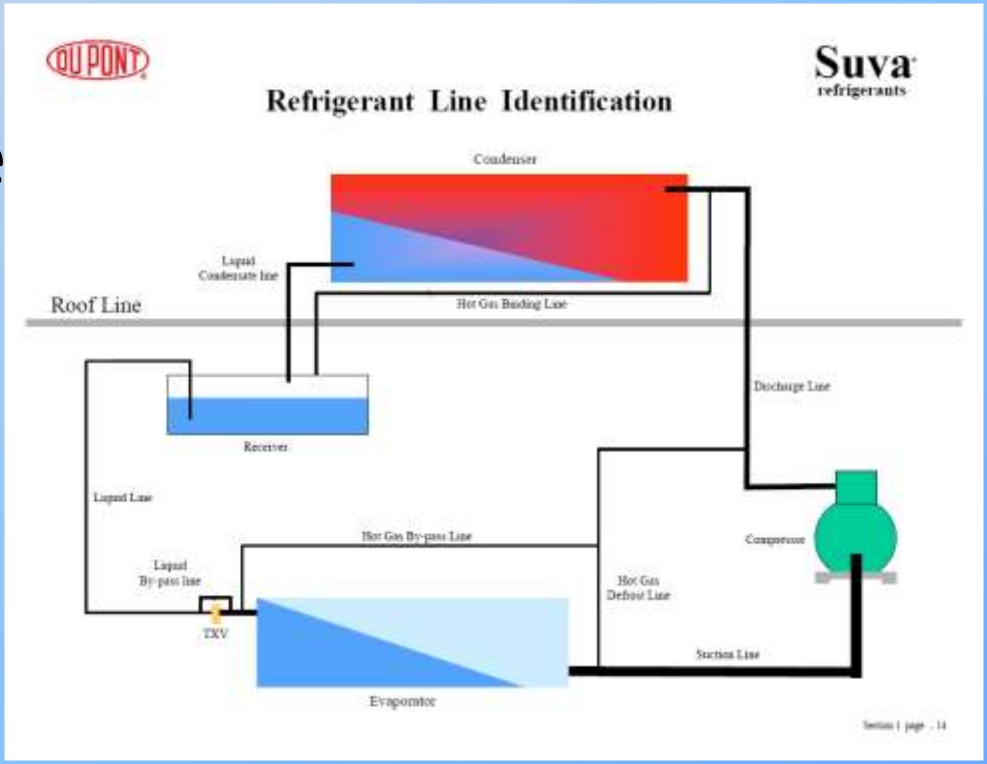
- Transport liquid refrigerant to the metering device
- Ensure that the fluid entering the metering device is fully liquid phase!
  (That's why we sub-cool)
- *Prevent heat gain in the refrigerant which would also heighten the risk of flash gas*

Size a Liquid Line

- Yes – use the charts.
- Don’t forget corrections for temperatures etc

Receivers – What / Where

- Systems do not always operate at the same conditions
- Need to address changing vapour / liquid ratios
- How does the oil get through the receiver – orifices and venturi effect



Vapour Migration

- Vapour Pressure driven
- Oil is always a lower vapour pressure than the surrounding refrigerant (at rest)
- Vapour moves to a lower "vapour pressure
  Colder areas of the system
  Oil resevoirs
- Just because you collected it in a receiver does not mean it will stay there.
- Vapour migration during shutdown can lead to catastrophic failures!

Now over to Mr Pinder

- Real life examples

REAL LIFE EXAMPLES

REAL LIFE EXAMPLES

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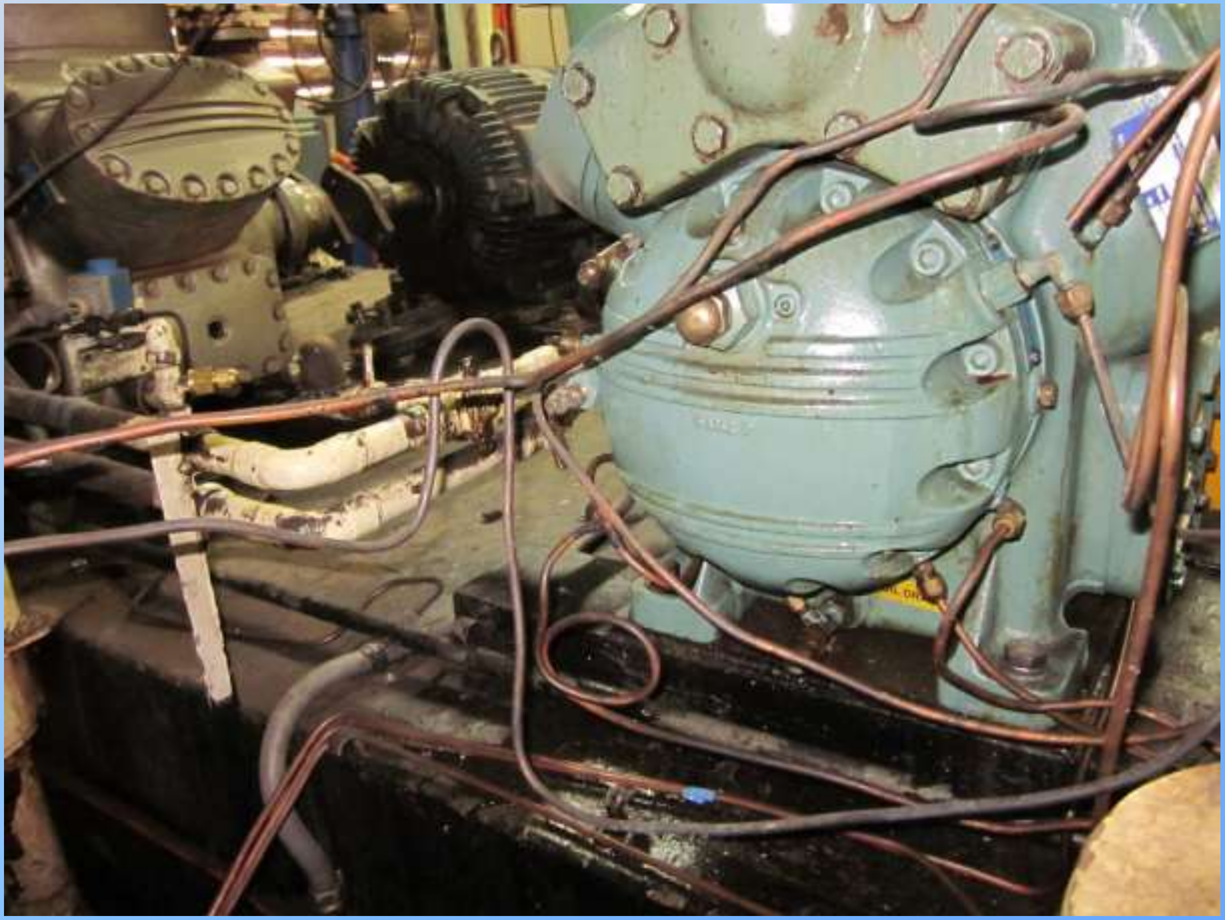


REAL LIFE EXAMPLES

REAL LIFE EXAMPLES

REAL LIFE EXAMPLES

A few to finish with

- It’s almost time for Drinks….

What might we change?

- Discharge Lines – should they be insulated or not?

- Liquid Line?

Replace with …

- Trapped
- Insulated

What would we change here?

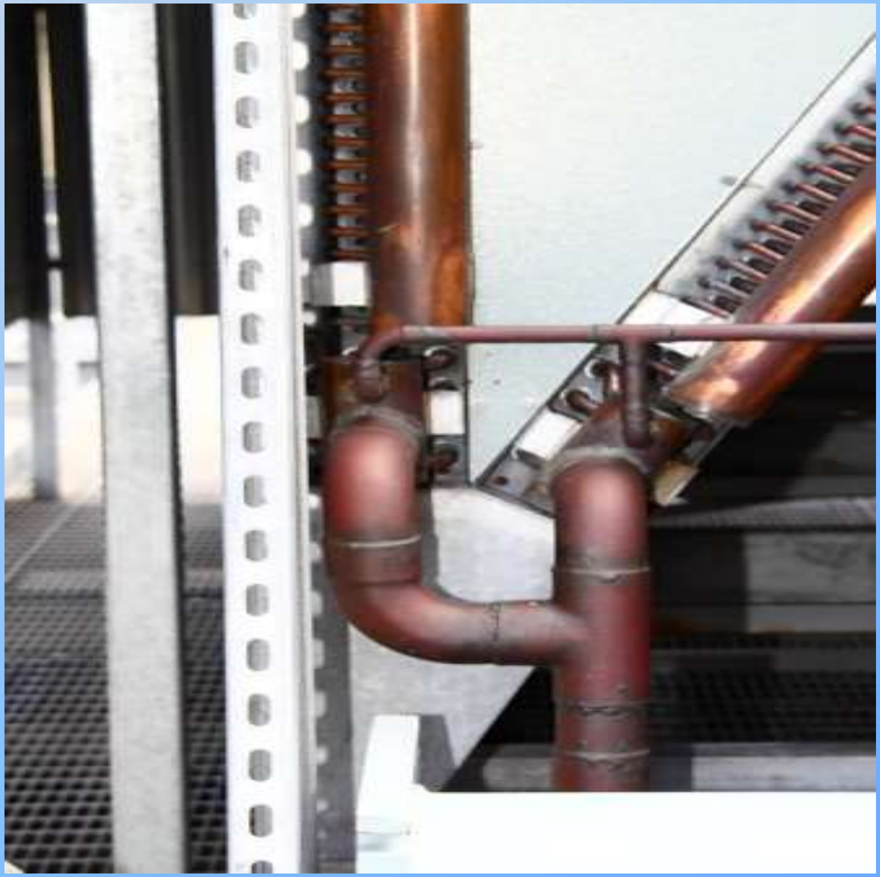
- Liquid Receiver
- SubCooled Line
- Liquid Line

Replaced with

- Liquid Receiver RELOCATED

A few to finish with

- Sub Cooled Liquid Line
- What does the liquid line have to do?



How about here ….

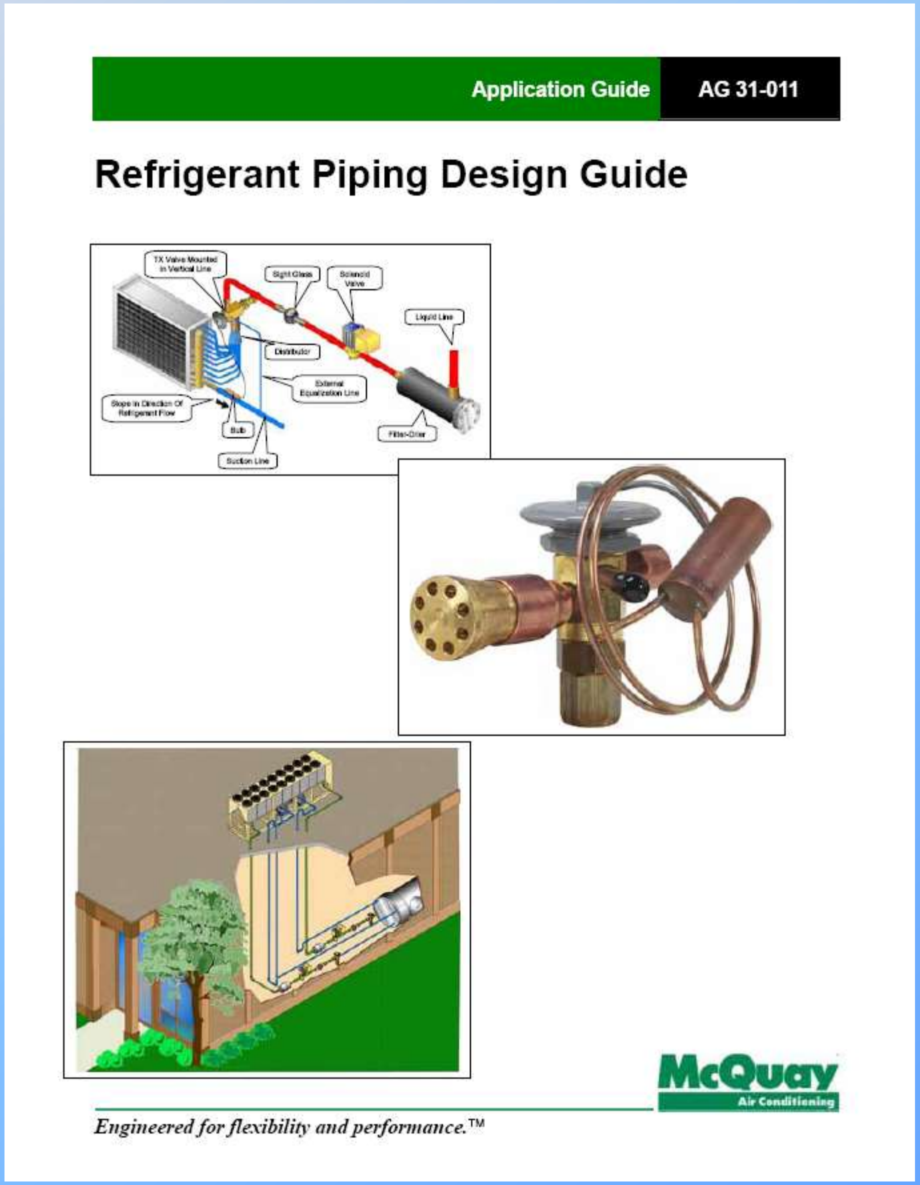
- Discharge Lines
- Check Valves

Replaced with …

Thanks for your time

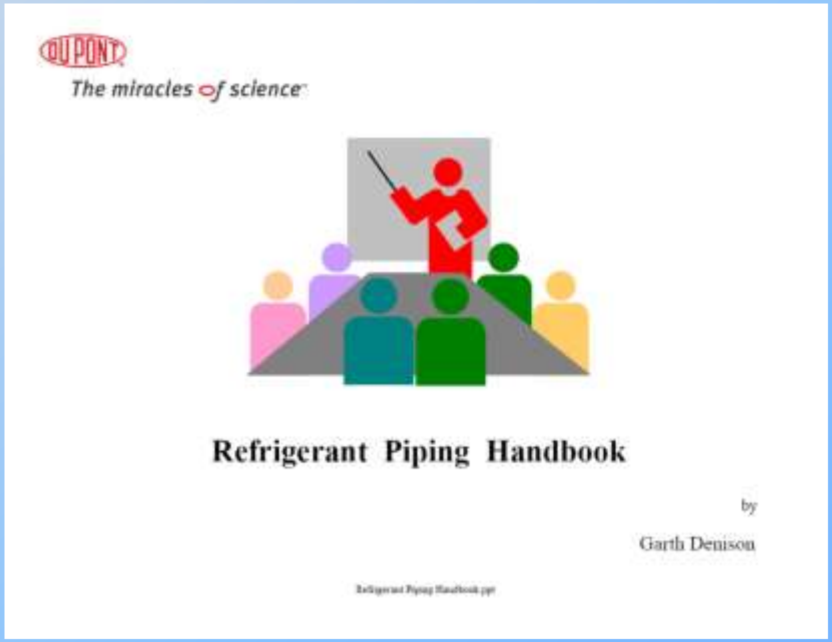
References

- McQuay Refrigerant Piping Design Guide



References

- Refrigerant Piping Handbook



References

- ASHRAE HANDBOOK 2

References

- A bundle of websites for images –

If we got this far in an hour ….

- How about some rules of thumb…

Rules of thumb

- For an R410a HVAC system the discharge line should be around 60-70 degrees normal max. If you can touch it for a moment … it's probably OK.
- If it SIZZLES there's trouble coming.
- If you can hold it, don't stand near the compressor – the bits coming out might hit you.

Rules of thumb

- The liquid line – SHOULD be either close to ambient or close within about 4 degrees of ambient wet bulb for water cooled.
- If it’s hot = not good
- If there are cold spots on it = not good

Rules of thumb

- Suction Line – might show some frosting after the TX.
- Should NOT be a block of ice.
- If there's a block of ice on the evap coil – again don't stand near the compressor.
- The suction line coming out of the evap should never be frosted

Rules of thumb

- Coil, compressor and Condenser sizing =
- Contact an expert!
- Do NOT forget that your Saturated Temperatures have CHANGED between compressor and condenser and between condenser and TX
- This changes capacity!