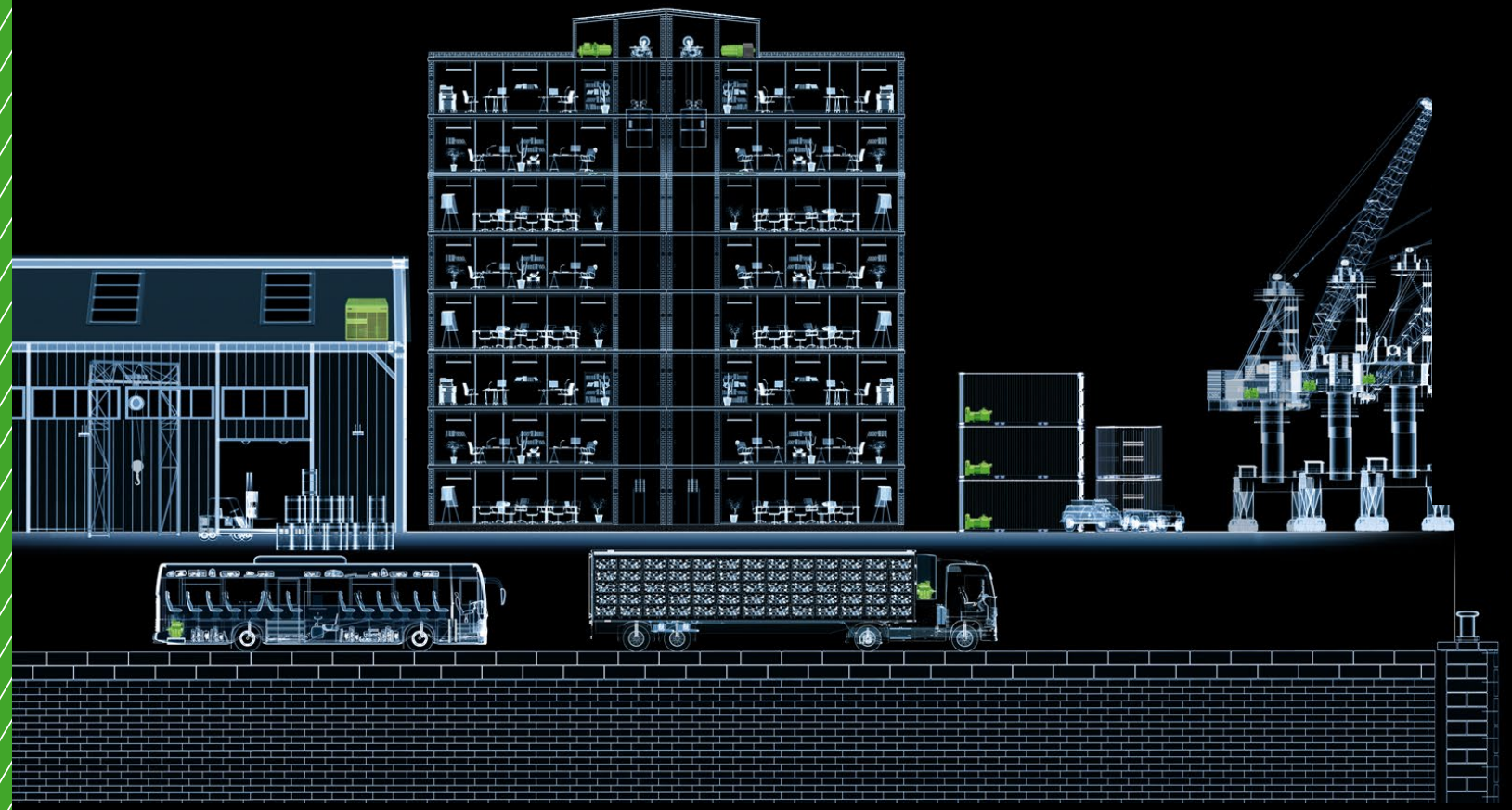

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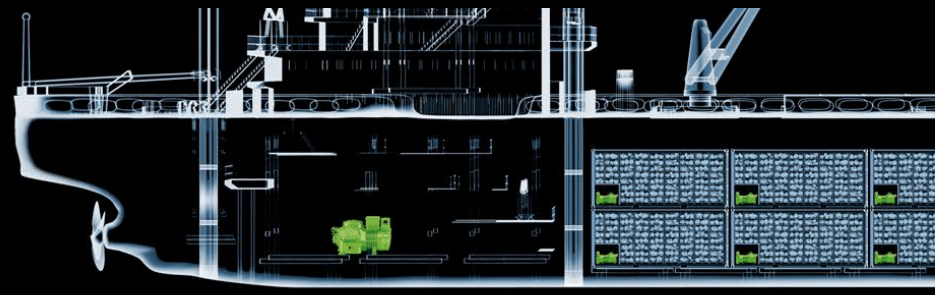


USING A DIGITAL TWIN SOFTWARE TO BETTER UNDERSTAND CO_2 AND AMMONIA REFRIGERATION

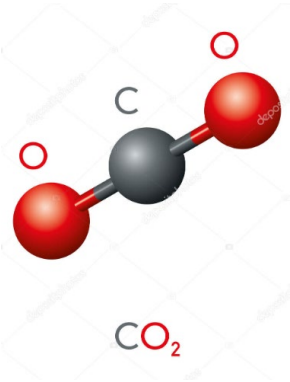
Joe Sanchez
September 9, 2025

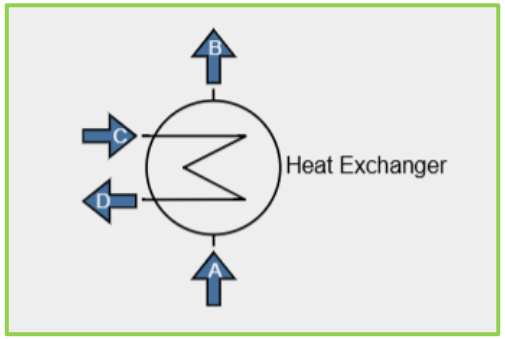
Fender

Bitzer
DAS HERZ DER FRISCHE

PURPOSE

// Ammonia and CO_2
  – Expanding into new applications
// Global De-Carbonization (or other Environmental Regulations)
  – Improved Energy Efficiency
  – Increase in Heat Pump “Technology”
  – Heat Recovery / Heat Transfer
// Reduced refrigerant charges
// Smarter and more sophisticated systems
  – Contextually designed not just on requirements – also location and other heat related opportunities





Today requires more holistic approaches to designing and understanding systems:

How can we **move** energy to where it needs to be?

Can we “up our game” ?

AGENDA // PLANNING

Part 1:

// Why a digital twin software? (3)
// Example: starting from scratch
// Refrigeration
// Refrigerants
// PH Diagram – Refrigerant Map (2)
// PH Diagram – simple Cycle (2)
// Thermodynamics (just one formula ☺)
// Example 2: Adding pipe, Subcooling, Superheat
// PH Diagram – Complex cycles
// CO2 and Ammonia (5)

25 Minutes

Part 2:

// Open Flash Comparison
// Heat reclaim / Heat pump
// Liquid Vapor Separation (NH3)
// CO2 Commercial Ref Systems (FGB, Parallel)
// Full Load vs. Part Load
  – Pipe sizing considerations, velocities
// Oil Sep sizing + oil cool (NH3)

25 Minutes

WHY A DIGITAL TWIN SOFTWARE?

Current Situation – Component & Hand Calcs

// Component software's are limited
- Can be myopic → Present data from component P.O.V.
- Often used as system software
  - E.g. A compressor output can provide Condenser / Evaporator Capacities

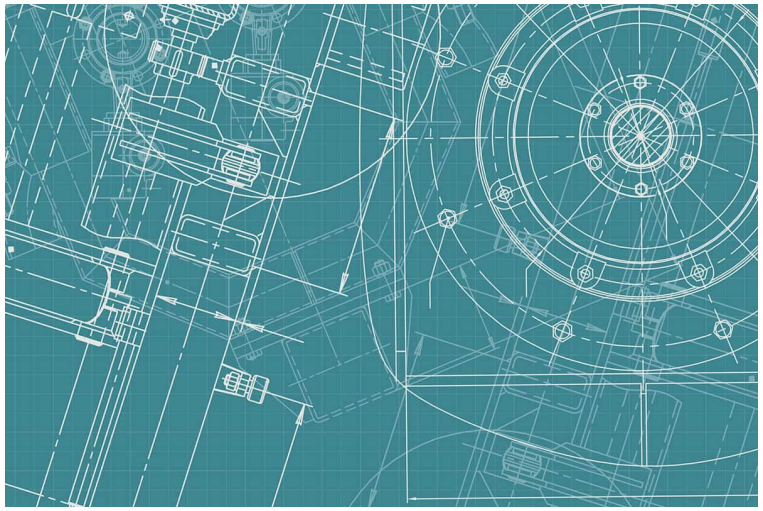
// System Balancing and Modeling
- Rules of thumb, guides, and assumptions
- Compressor vs. HX vs. System

// Potential issues related to assumption and / or confusion of:
- Superheat (evap / useful)
- Return Gas Temp
- Subcooling (in condenser vs. natural)
- Safety Factors (product, building, component, system, etc.)

→Need integrated digital tools for comprehensive systems

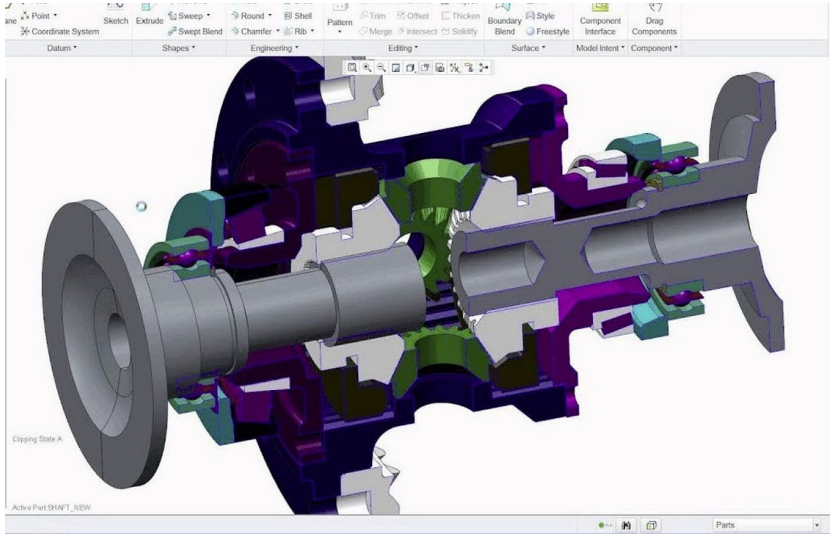
WHY A DIGITAL TWIN SOFTWARE: ANALOGY

// Hand Drawn



vs.

CAD Drawing



WHY A DIGITAL TWIN SOFTWARE: BENEFITS

// Design Time
- Improving overall accuracy and speed of key design decisions
- Selecting optimal system architecture (fast comparisons)
- Better understanding of cost vs. efficiency benefit
  - Internal heat exchangers, Pipe Sizing, etc.
- Reduce confusion → Better communication

// Saving $$
- Lower the system cost by understanding and minimizing safety factors
- Lower energy bill by selecting an efficient design

// Maintain (End Users & Technicians)
- Simplify troubleshooting with a “digital twin”
- Get “rookies” trained faster on the fundamentals

→ Lets see!

STARTING AT ZERO: AS YOU KNOW.. REFRIGERATION IS…

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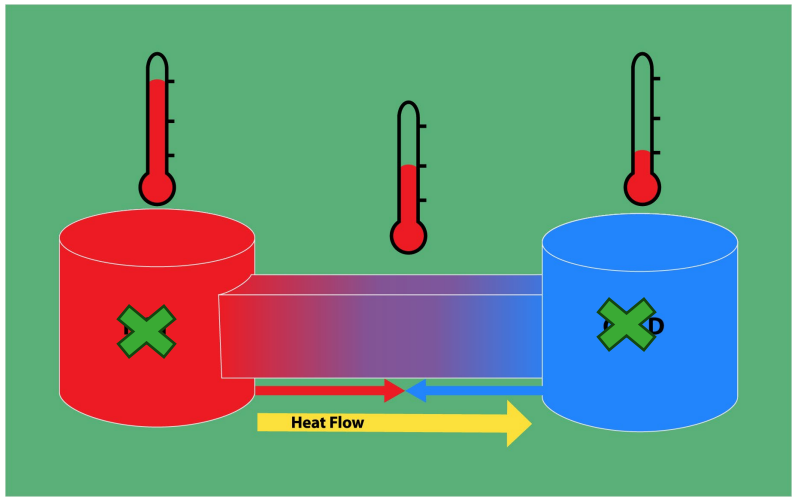
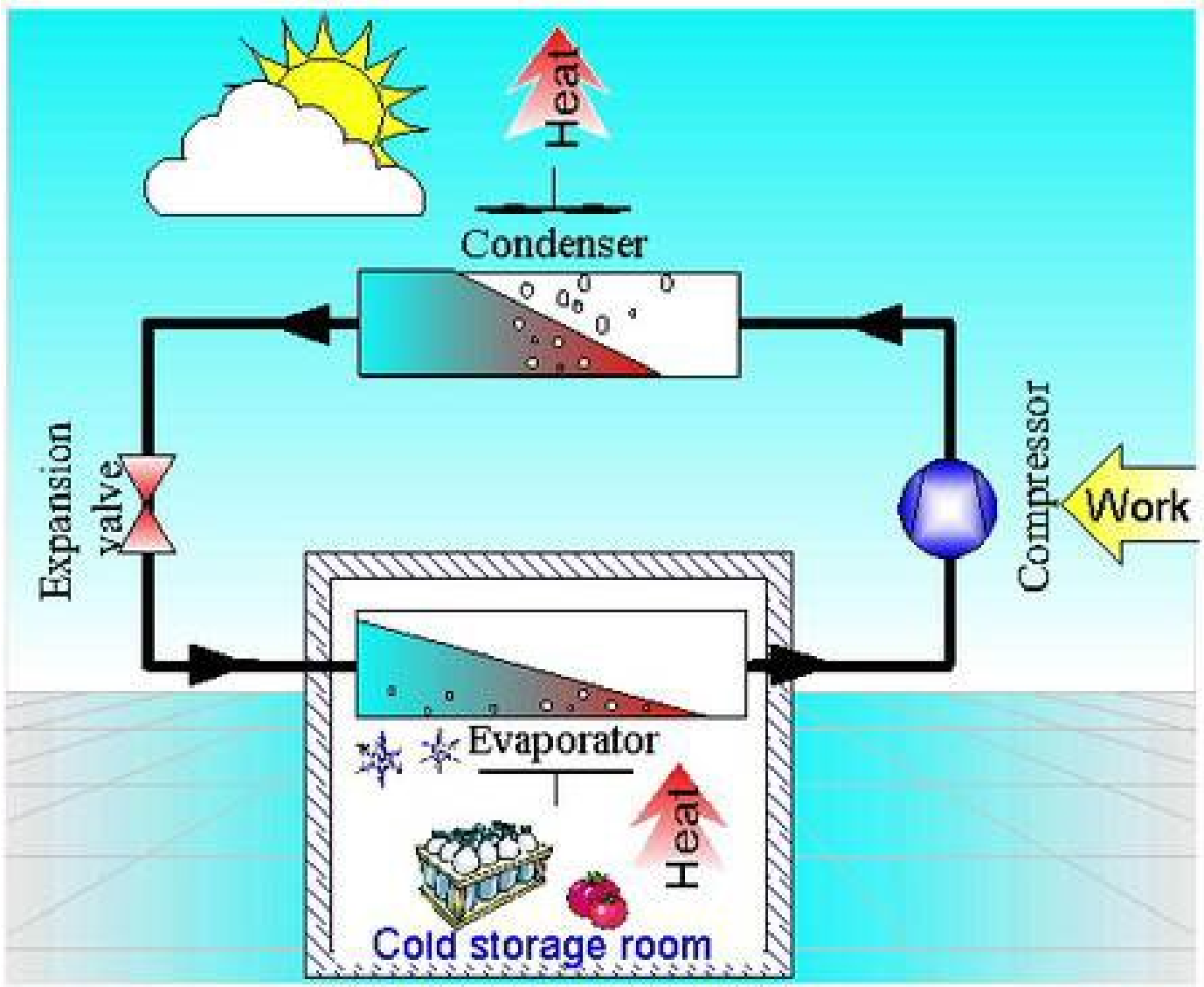
- Using a fluid to absorb heat at one temperature
- And releasing that heat at a higher temperature

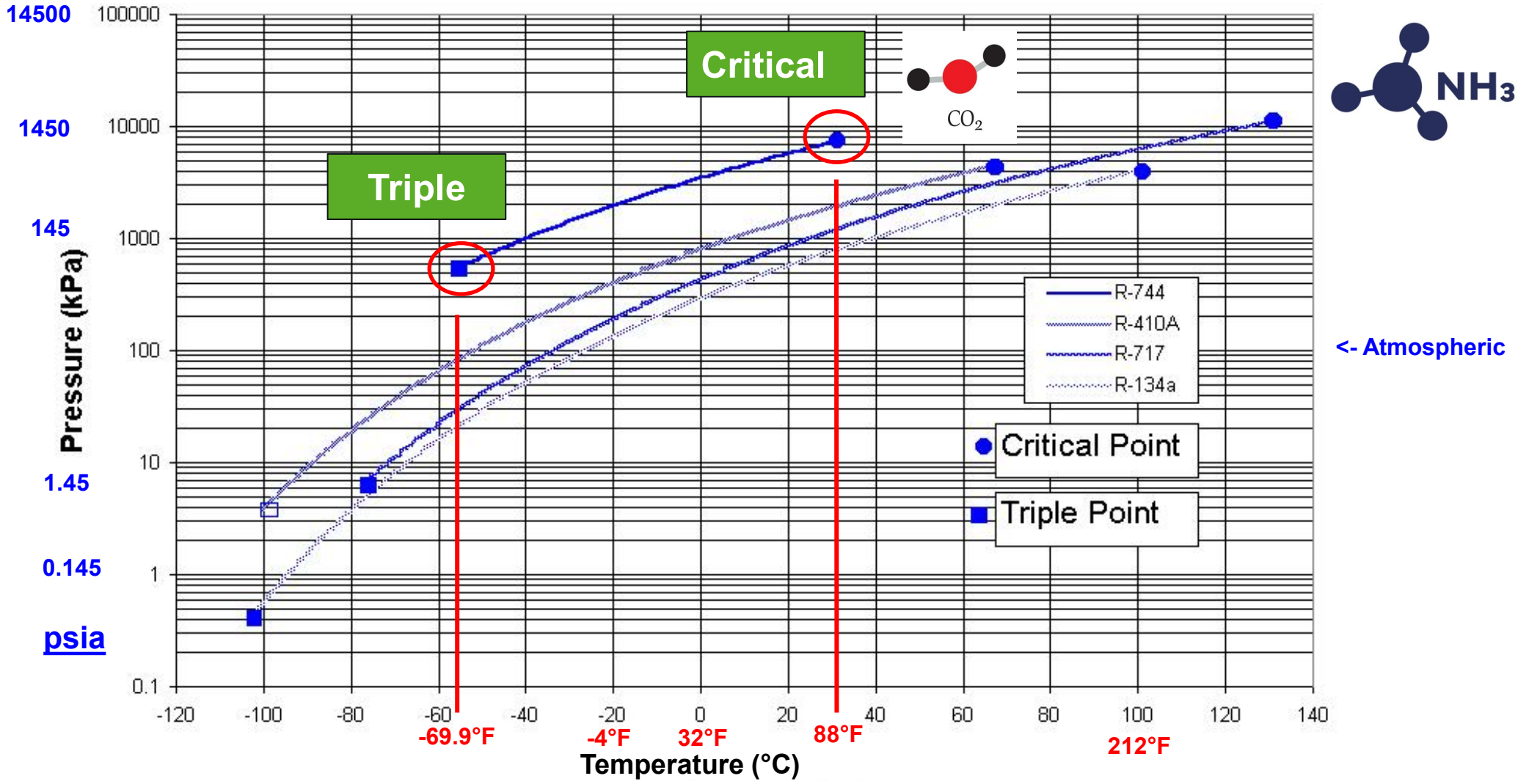
In other words, **move** heat against the *natural flow*:



Higher Temp → Lower Temp

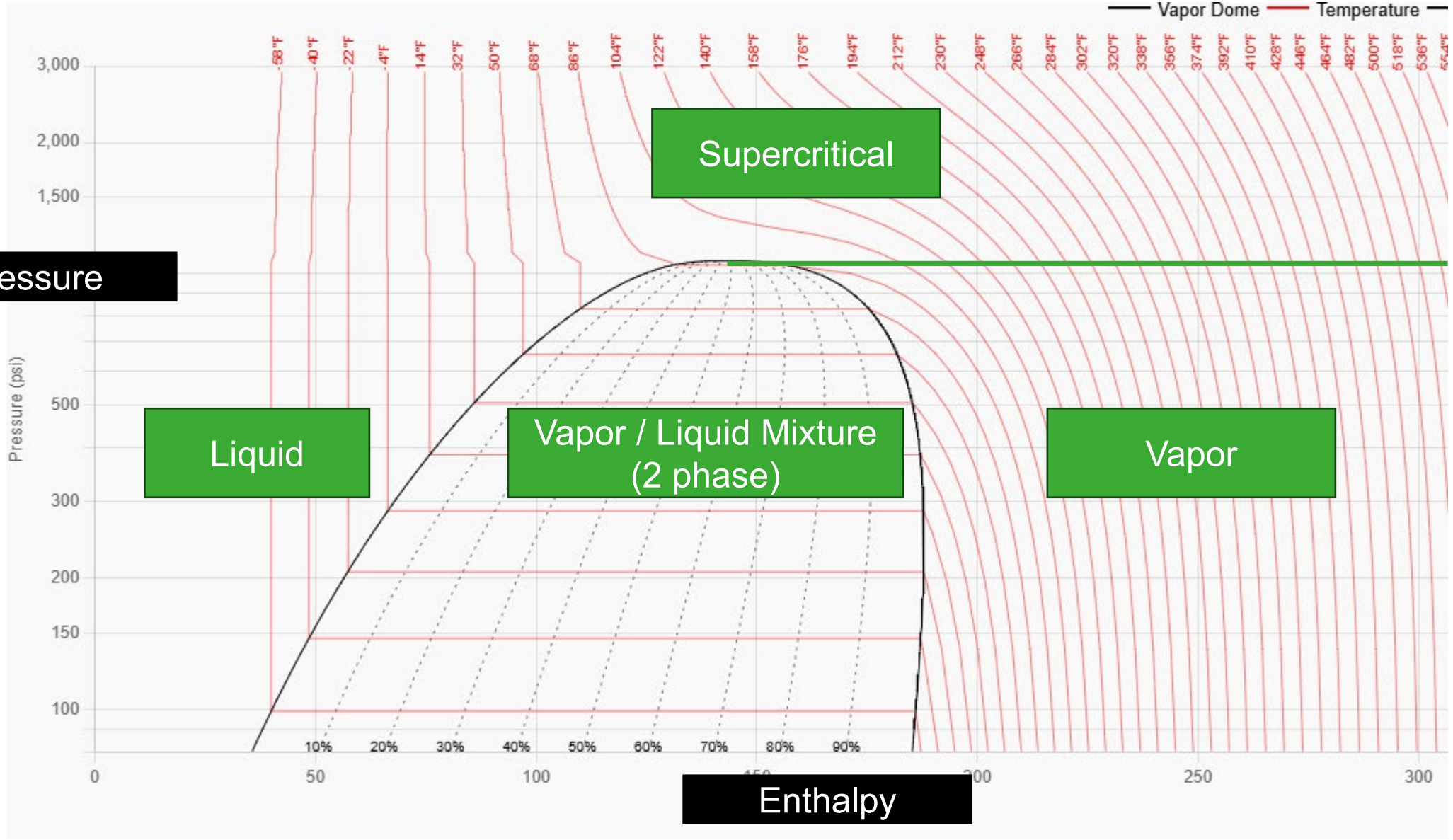


REFRIGERANTS



Reference: The Institute of Refrigeration (2003) .Safety code for refrigeration systems utilizing Carbon Dioxide.

REFRIGERANT PH DIAGRAM(1)



REFRIGERANT PH DIAGRAM(2)

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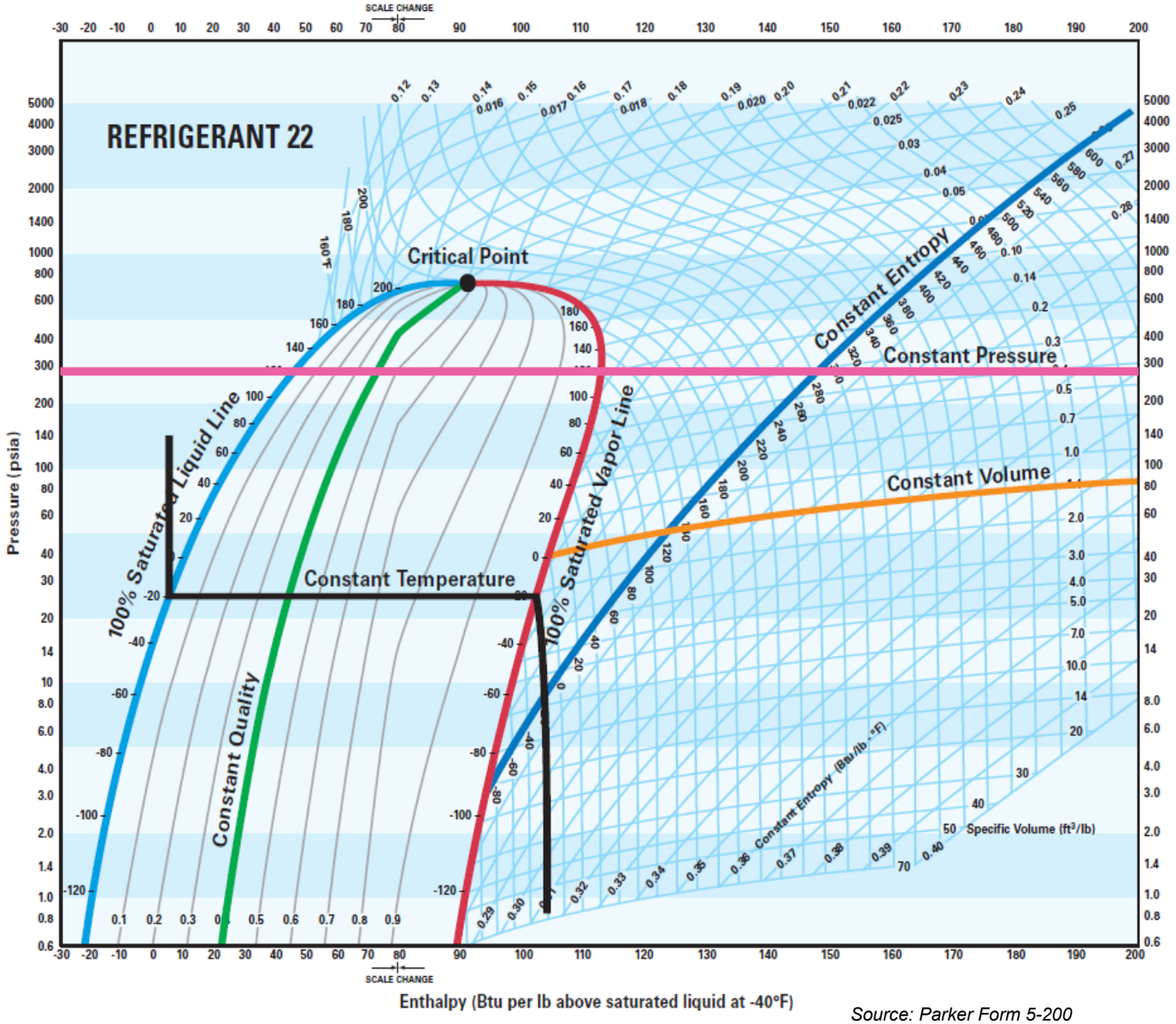
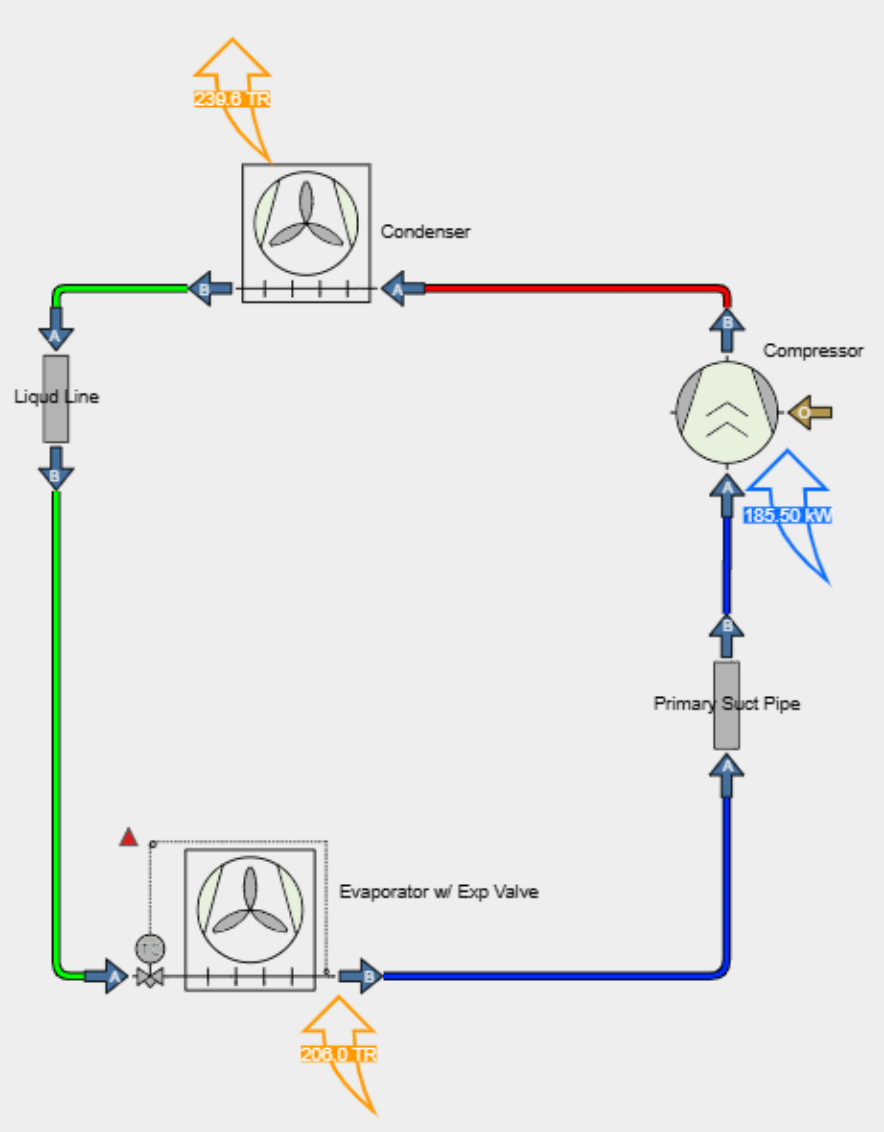
// Map of Refrigerant

- "The Vapor Dome"
  - 100% Liquid Line (Bubble point)
  - 100% Vapor Line (Dew point)
  - Critical Point
- Quality (0: 100% Liquid, 1: 100% Vapor)
- Pressure: "P"
- Enthalpy: "h" (must be relative)
- **Temperature "T"**
- **Density / Specific Volume: "d / v"**
- **Entropy: "s"**



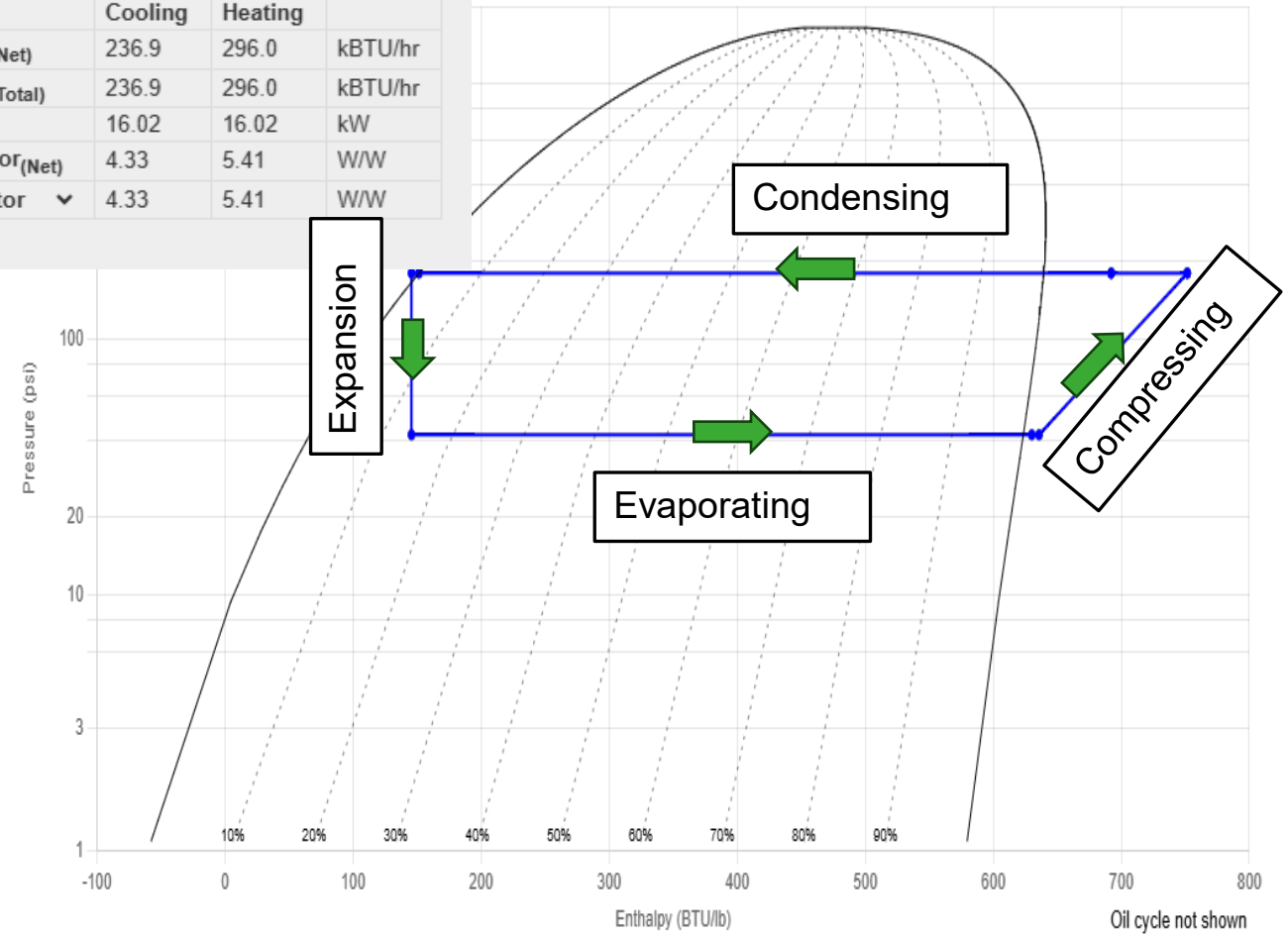
Source: Parker Form 5-200

USING THE PH DIAGRAM – PART 1



PERFORMANCE FACTORS

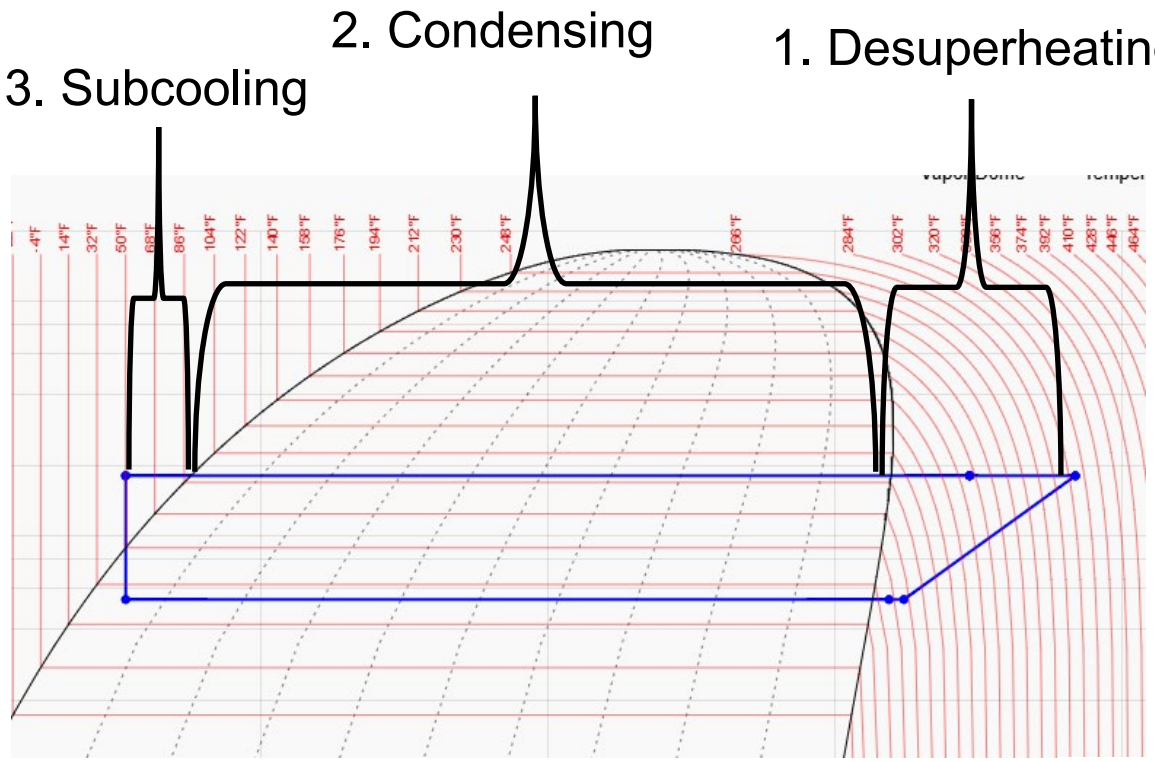
	Cooling	Heating	
Capacity(Net)	236.9	296.0	kBTU/hr
Capacity(Total)	236.9	296.0	kBTU/hr
Power	16.02	16.02	kW
Perf. Factor(Net)	4.33	5.41	W/W
Perf. Factor	4.33	5.41	W/W



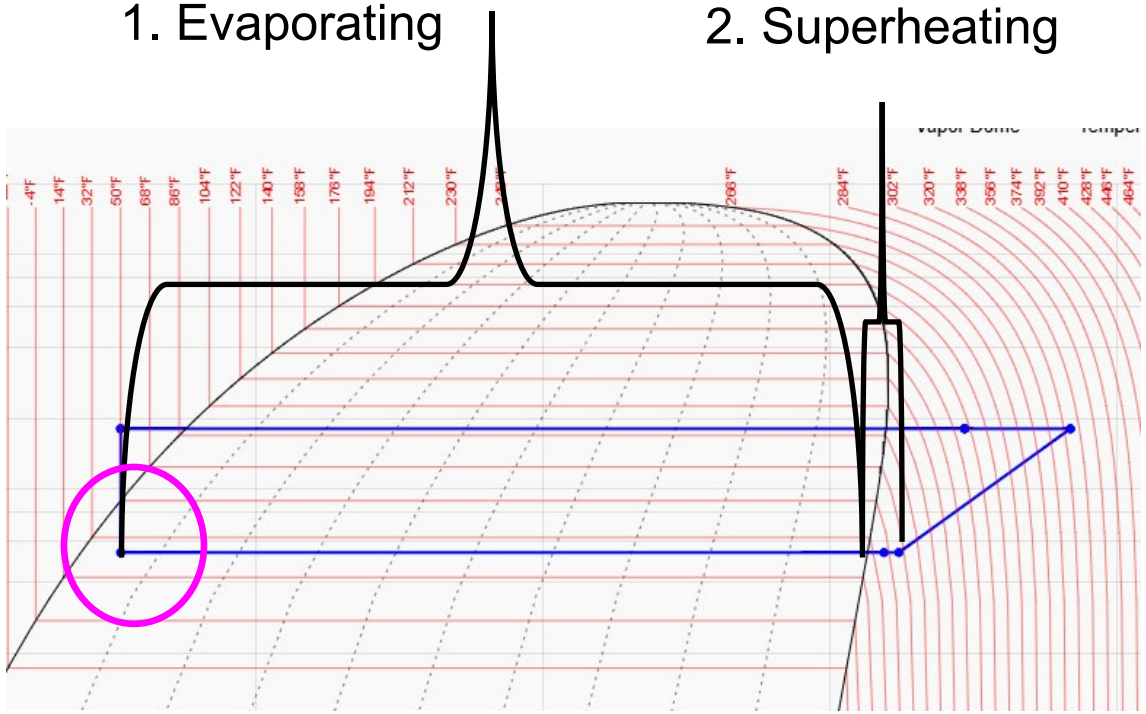
NH_3

USING THE PH DIAGRAM – PART 2

Condenser



Evaporator

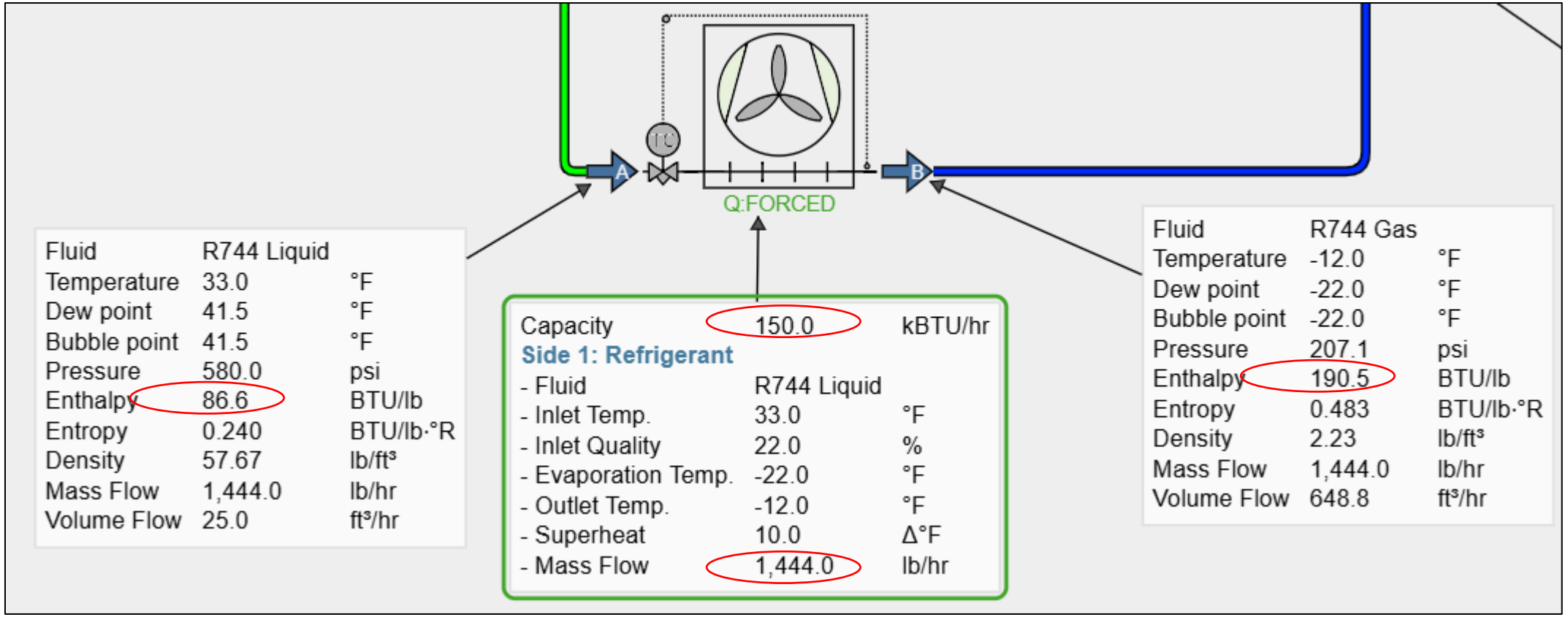


NH_3

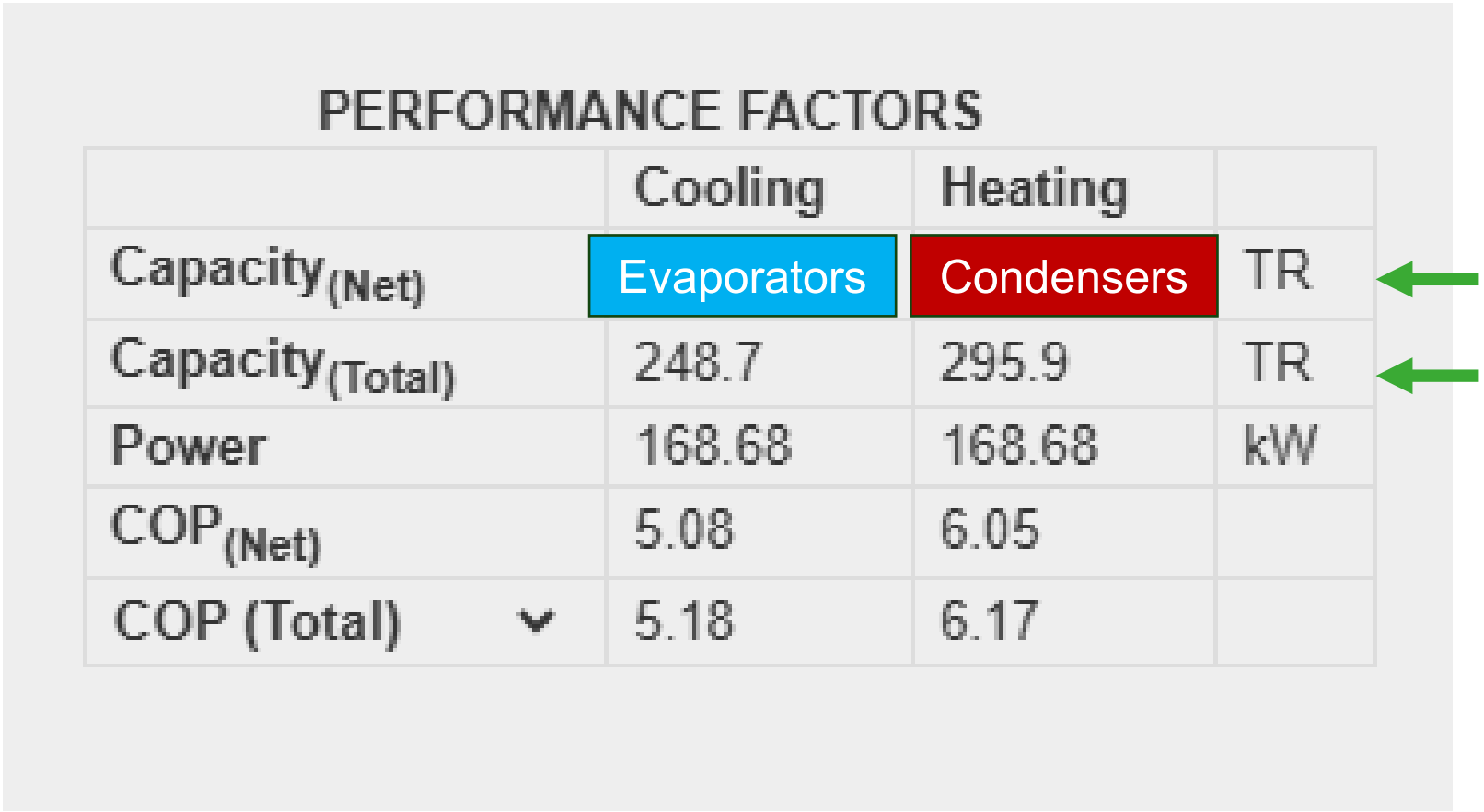
JUST ONE FORMULA

// Capacity = Mass flow (lb/h) * Change in Enthalpy (Btu/lb)

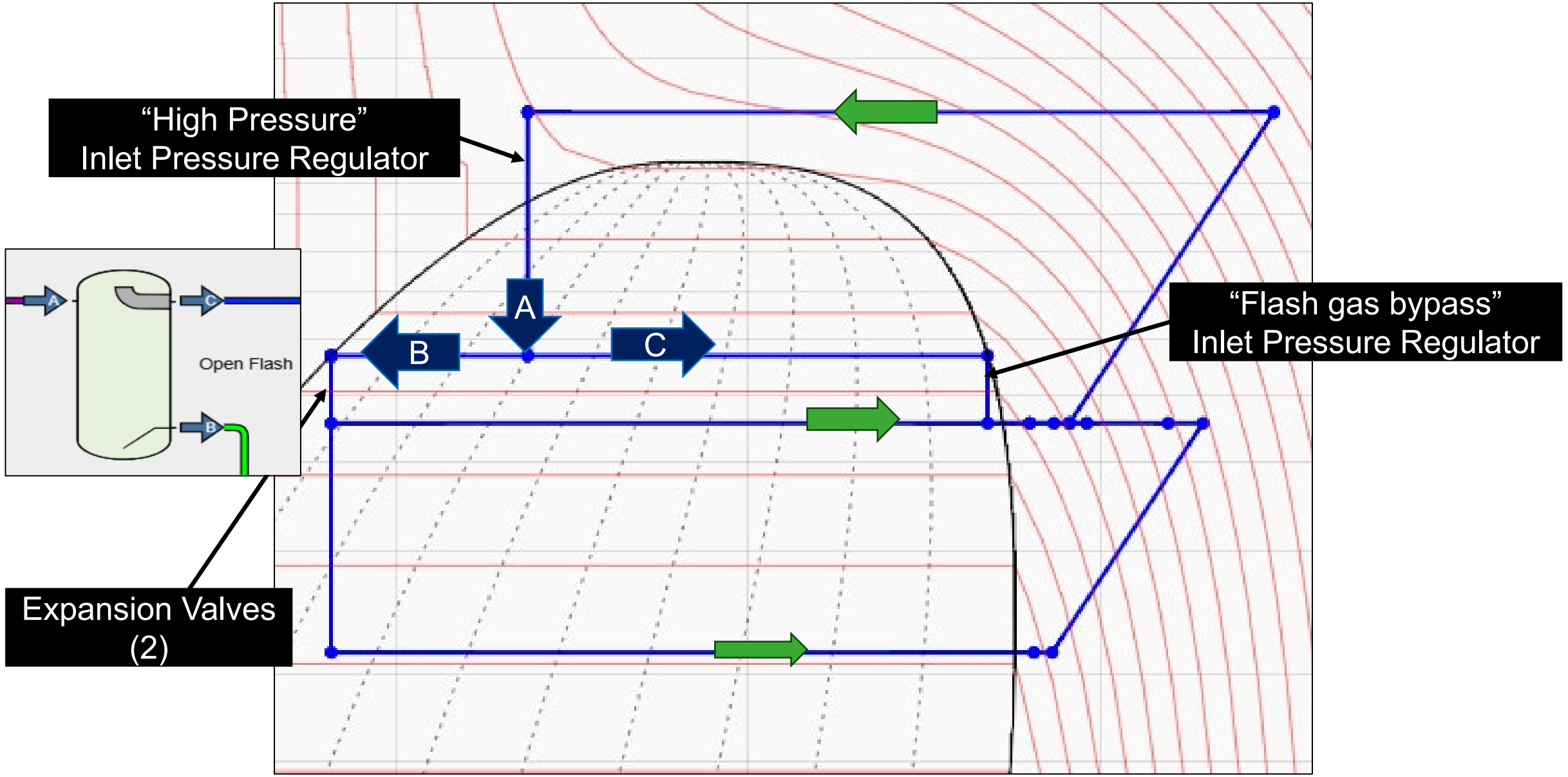
$$Q = \dot{m} * \Delta h = \dot{m} * (h_{out} - h_{in})$$



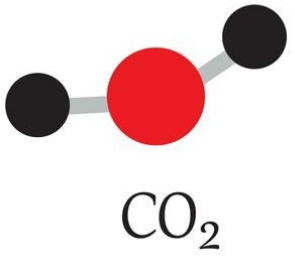
CAPACITIES OVERVIEW



USING THE PH DIAGRAM - PART 3

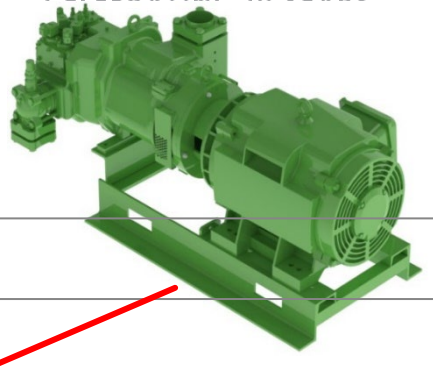


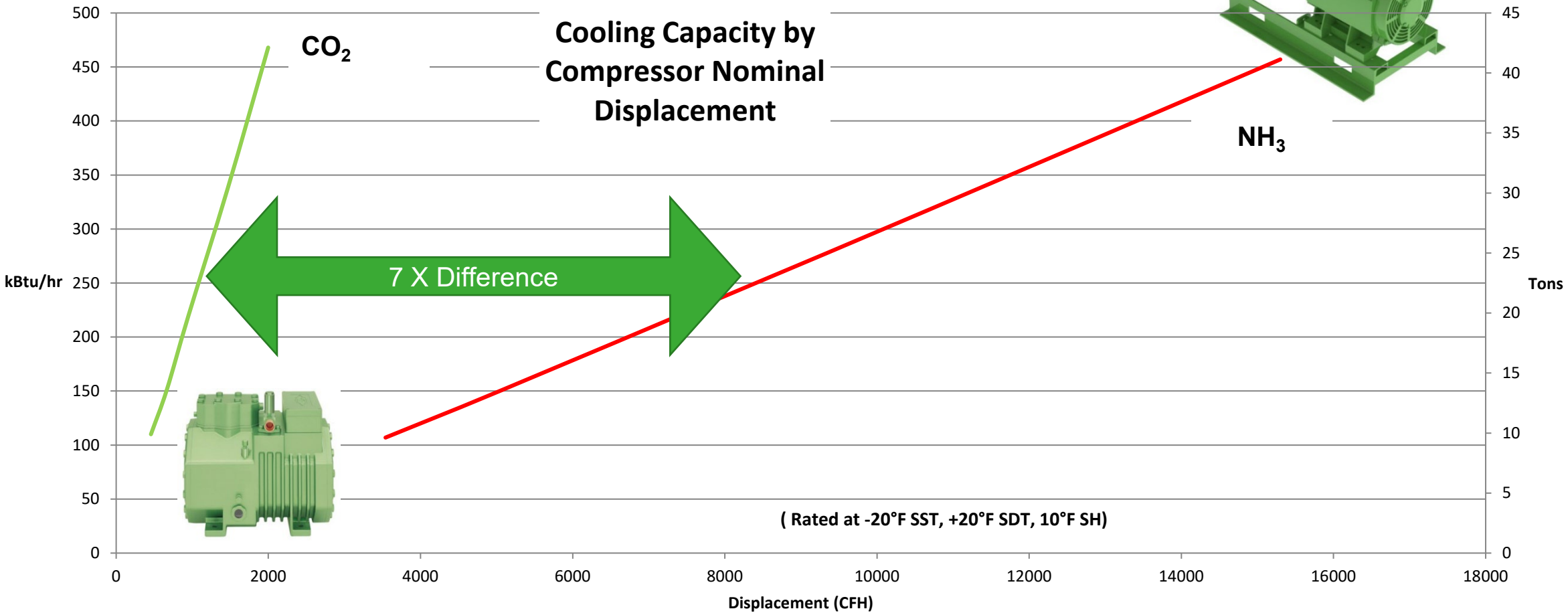
AMMONIA AND CO_2 COMPARISON



Property / Factor	Ammonia (NH_3, R717)	Carbon Dioxide (CO_2, R744)
Efficiency	Very high (low-temp applications)	Good, but less efficient at low temps unless cascaded
Operating pressure	Moderate	Very high (esp. in transcritical cycle)
Toxicity / Safety	Toxic, corrosive, detectable by smell	Non-toxic, but asphyxiant at high conc.
Flammability	Slightly flammable	Non-flammable
Materials compatibility	Corrosive to copper (uses steel piping)	Compatible with most materials
Typical applications	Large industrial plants, food processing, ice rinks	Supermarkets, transport, heat pumps, cascade with NH_3
Environmental impact	ODP = 0, GWP = 0	ODP = 0, GWP = 1
Cost & availability	Widely available, inexpensive	Widely available, inexpensive

AMMONIA AND CO_2 COMPARISON





AMMONIA AND CO_2 COMPARISON

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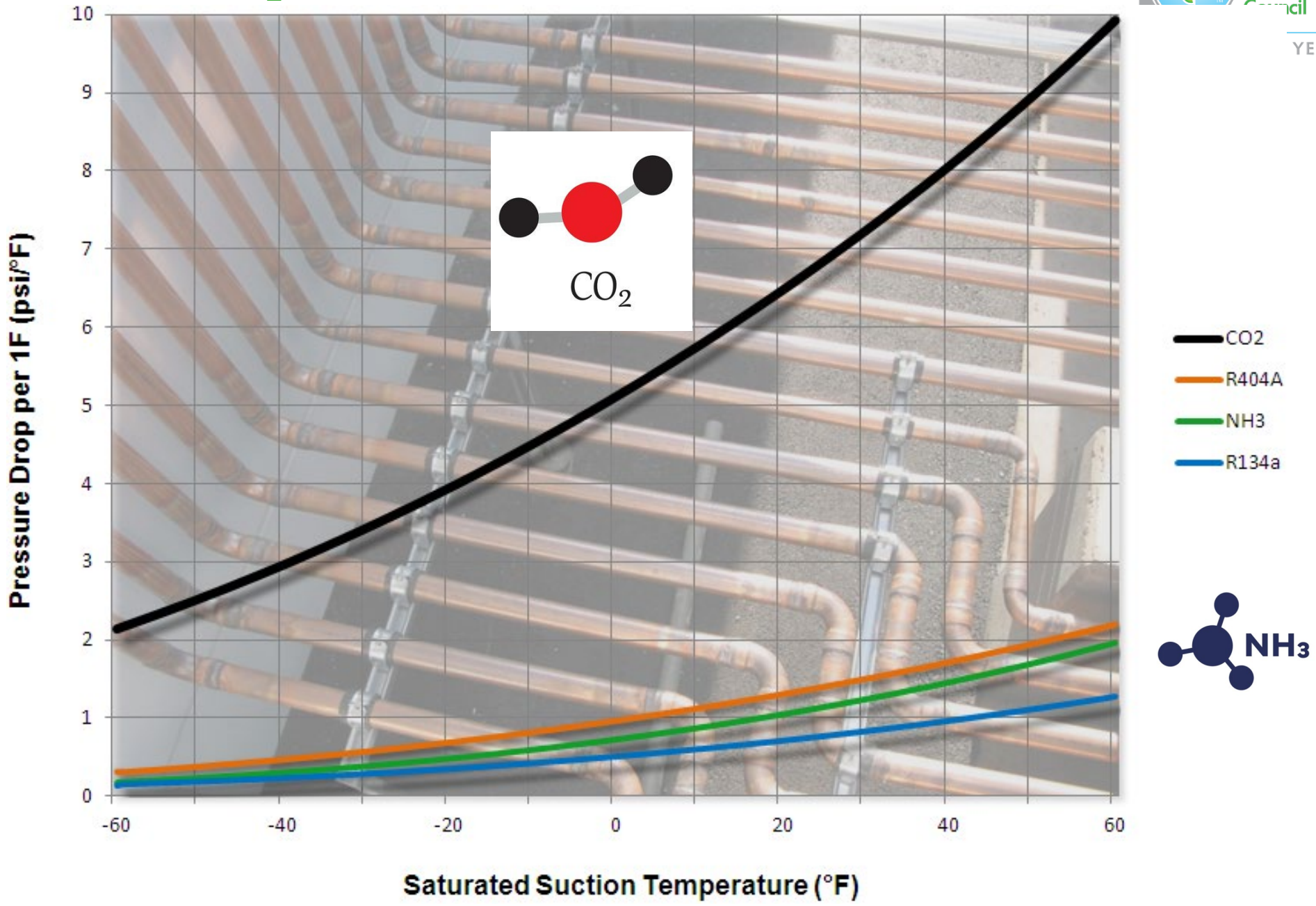
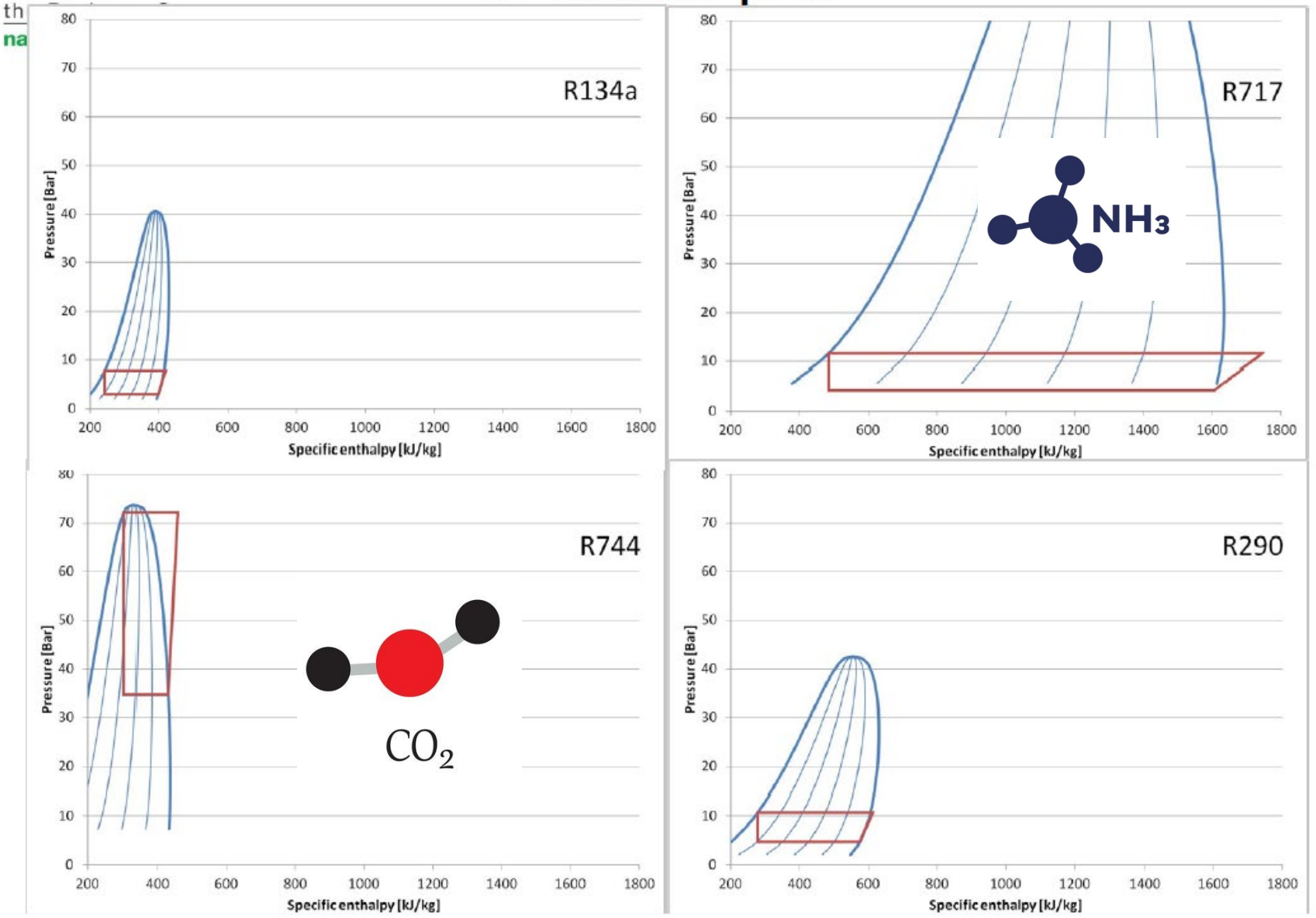
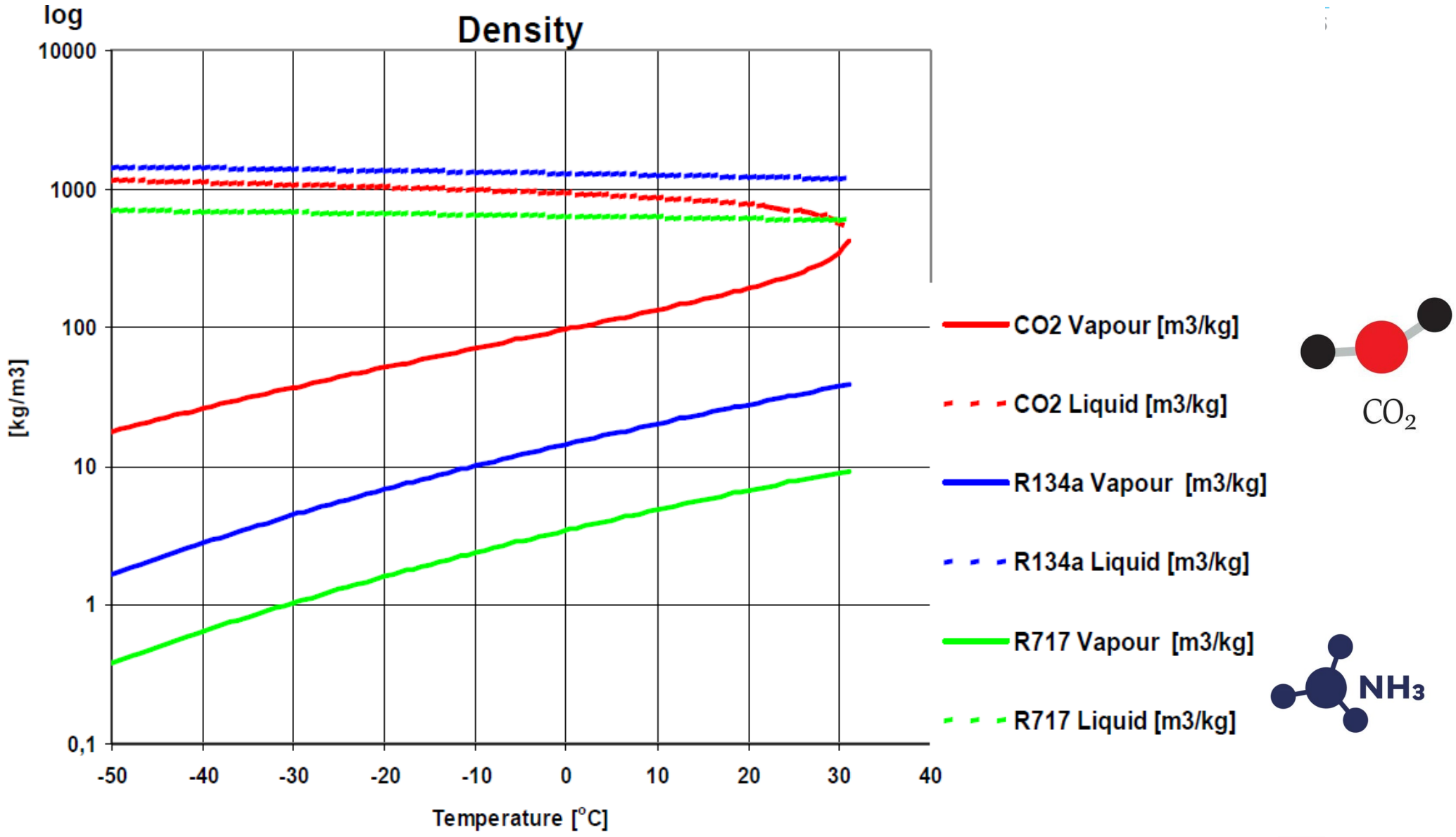
10 YEARS



In scale: p-h


R134a
R717
NH3
R744
CO2
R290
Pressure [Bar]
Specific enthalpy [kJ/kg]
0
10
20
30
40
50
60
70
80
200
400
600
800
1000
1200
1400
1600
1800

AMMONIA AND CO_2 COMPARISON



https://fender.bitzerpv.com