Understanding Supermarket Transcritical Carbon Dioxide (CO_2) Refrigeration Systems

April 6, 2021

Call-in Details 1-202-991-0477 ID: 809 728 562#

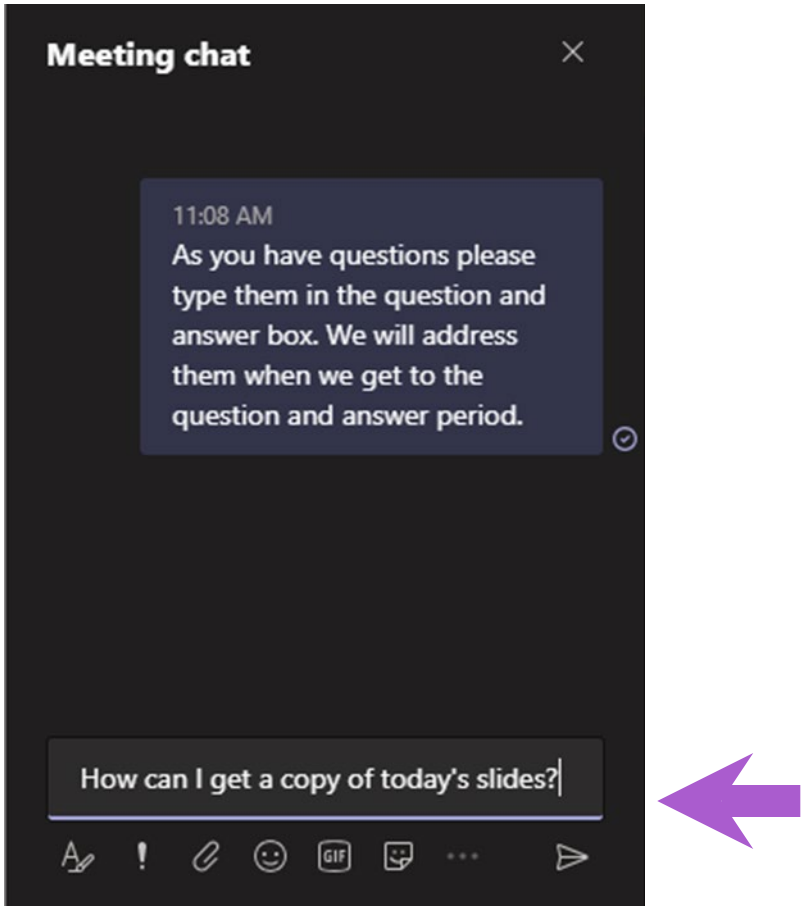
Questions and Webinar Feedback

Question and Answer Session

- Participants are muted
- Questions will be moderated at the end
- To ask a question, enter your comment into the chat box

Feedback Form

- We value your input!
- The link to a feedback form will appear in the chat window



Webinar Materials

Recording and Slides

- Webinar is being recorded
- Materials will be posted on the GreenChill website under Events and Webinars: www.epa.gov/greenchill
- To receive notification when materials are posted email: EPA-GreenChill@abtassoc.com

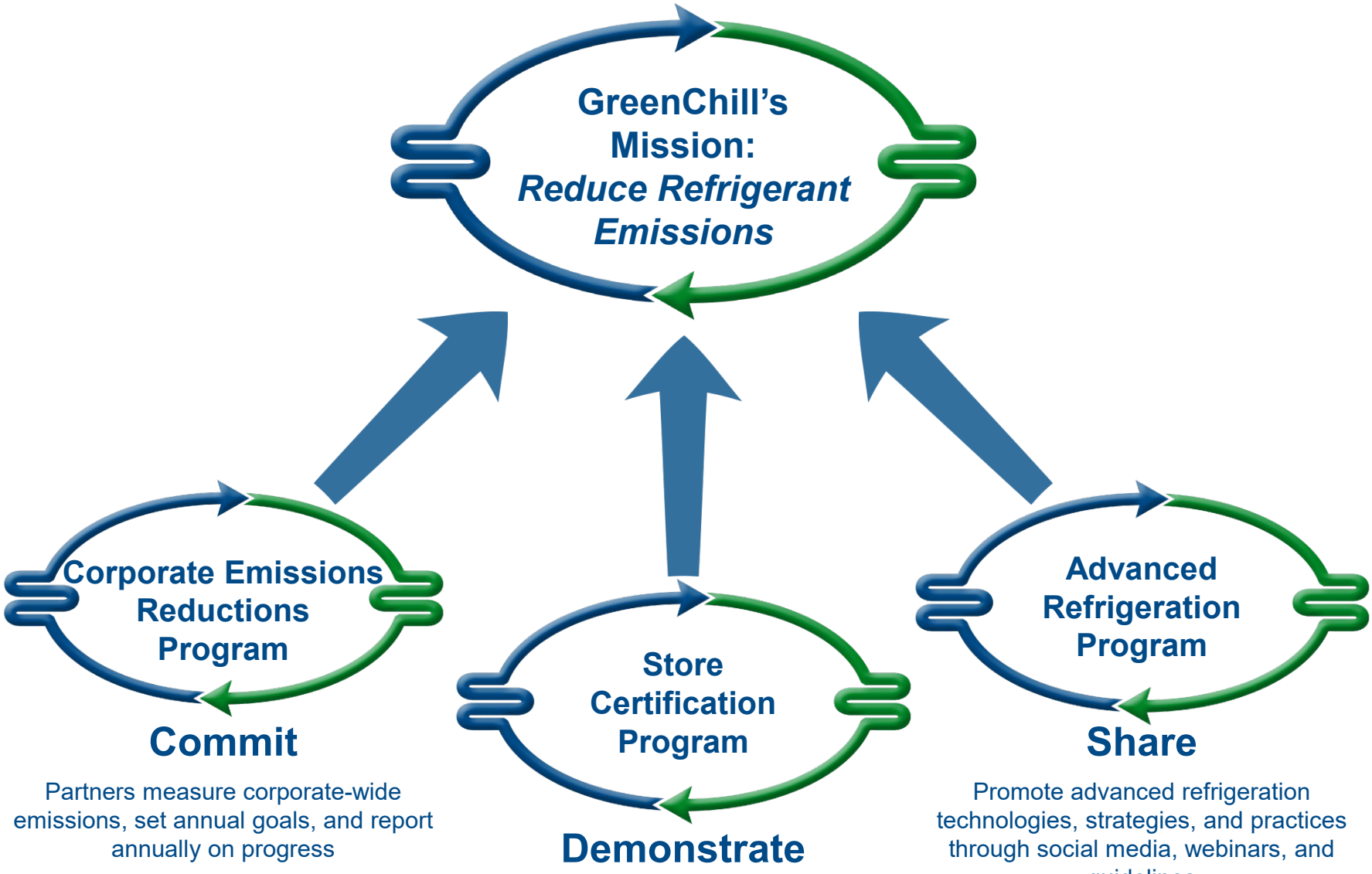
Program Overview

GreenChill is a voluntary partnership program that works collaboratively with the food retail industry to reduce refrigerant emission and decrease stores' impact on the ozone layer and climate system

GreenChill works to help food retailers:

- Lower refrigerant charge sizes and eliminate leaks
- Transition to environmentally friendlier refrigerants
- Adopt green refrigeration technologies and best environmental practices

www.epa.gov/greenchill


GreenChill's Mission: *Reduce Refrigerant Emissions*
Corporate Emissions Reductions Program
Commit
Partners measure corporate-wide emissions, set annual goals, and report annually on progress
Store Certification Program
Demonstrate
Individual stores earn GreenChill certification for meeting highest standards: low charge size, use of less harmful refrigerants, and low leak rates
Advanced Refrigeration Program
Share
Promote advanced refrigeration technologies, strategies, and practices through social media, webinars, and guidelines

Learn More

www.linkedin.com/groups/1426947/

www.epa.gov/greenchill

GreenChill@epa.gov

Today's speakers…

Rob Arthur

Rob Arthur
Cushing Terrell
Director of Retail/Principal
Phone: 406-544-7825
Email: robarthur@cushingterrell.com

Rob is Director of Cushing Terrell's Retail Design Team and Principal-in-Charge of Refrigeration Engineering. He is dedicated to putting forth cutting-edge solutions and systems that result in high-efficiency, low-emission refrigeration systems. With a focus on helping the grocery industry transition to more technologically advanced, sustainable refrigeration systems, Rob works to provide high-quality designs for facilities. Keeping cost, installation needs, and serviceability top of mind, he designs systems that are environmentally responsible and make long-term sense. Rob is a LEED-accredited professional and a licensed professional engineer in 28 U.S. states, British Columbia, Alberta, Ontario, Saskatchewan and Puerto Rico.

Eric Nelson

Eric Nelson
Cushing Terrell
Title: Mechanical PE/Associate
Phone: 208-577-5661
Email: ericnelson@cushingterrell.com

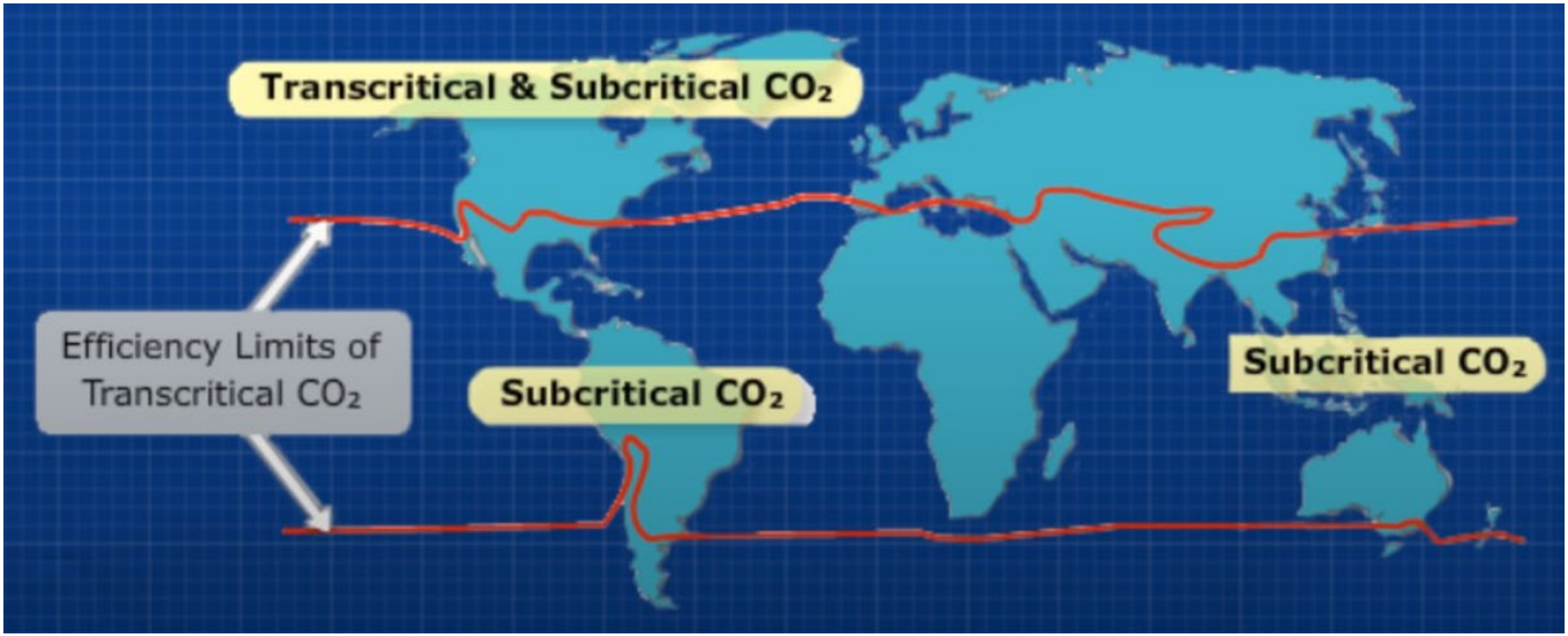
Eric has enjoyed a variety of roles in the refrigeration industry as a consulting engineer with Cushing Terrell. He has designed systems in large program rollouts, developed new solutions for unique problems, and performed energy modeling to help build the case for new systems or applications. He specializes in finding simple solutions to complex problems through the application of fundamental principles.

Understanding Supermarket Transcritical Carbon Dioxide Refrigeration Systems

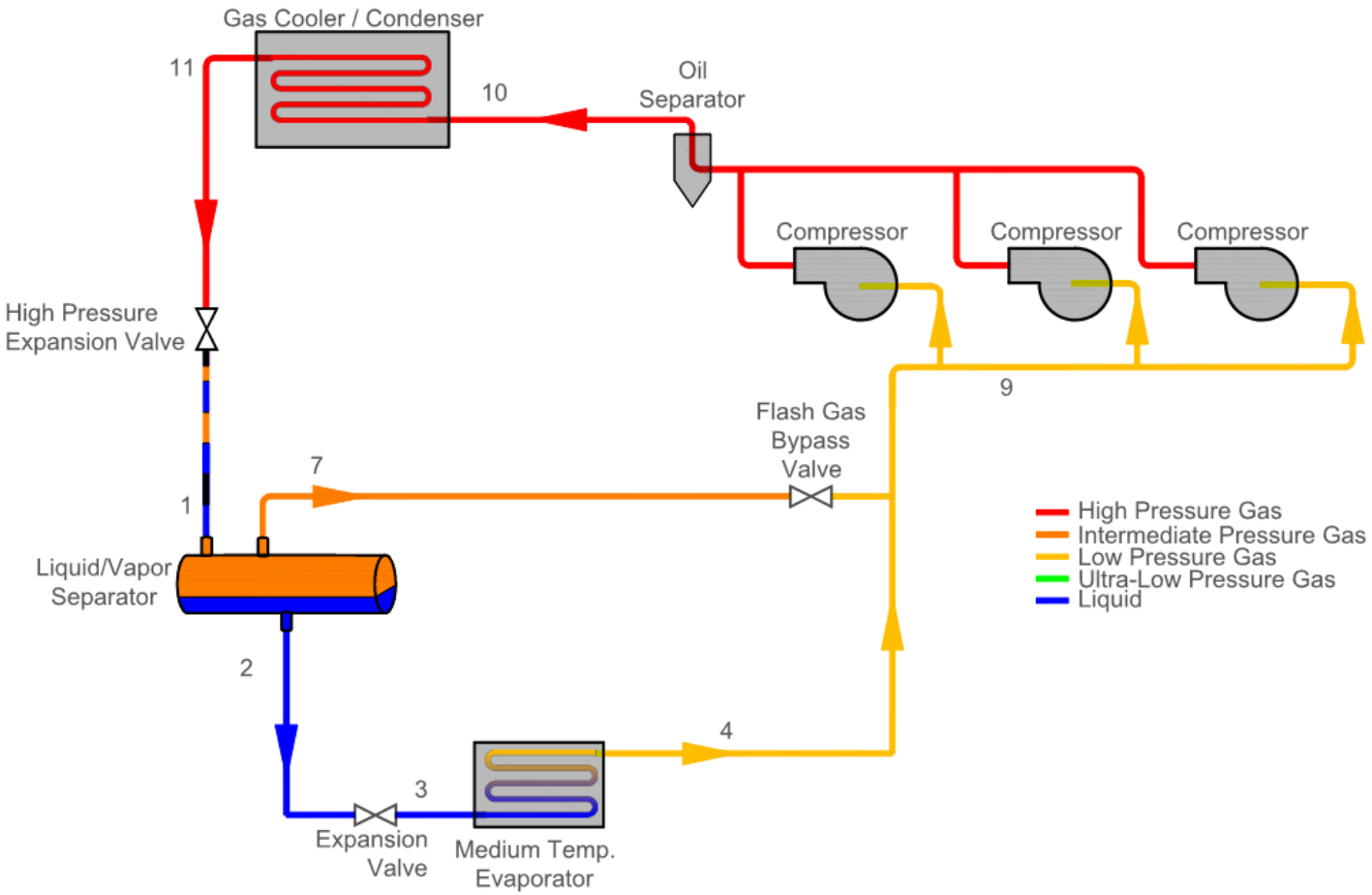
CO_2 Refrigeration System

- Transcritical
  - Subcritical
  - Transcritical Booster
  - Adiabatic Gas Cooler
  - Parallel Compression
  - Ejectors
  - Full Transcritical Efficiency (FTE)
  - Subcooling and Desuperheater
  - Other Strategies

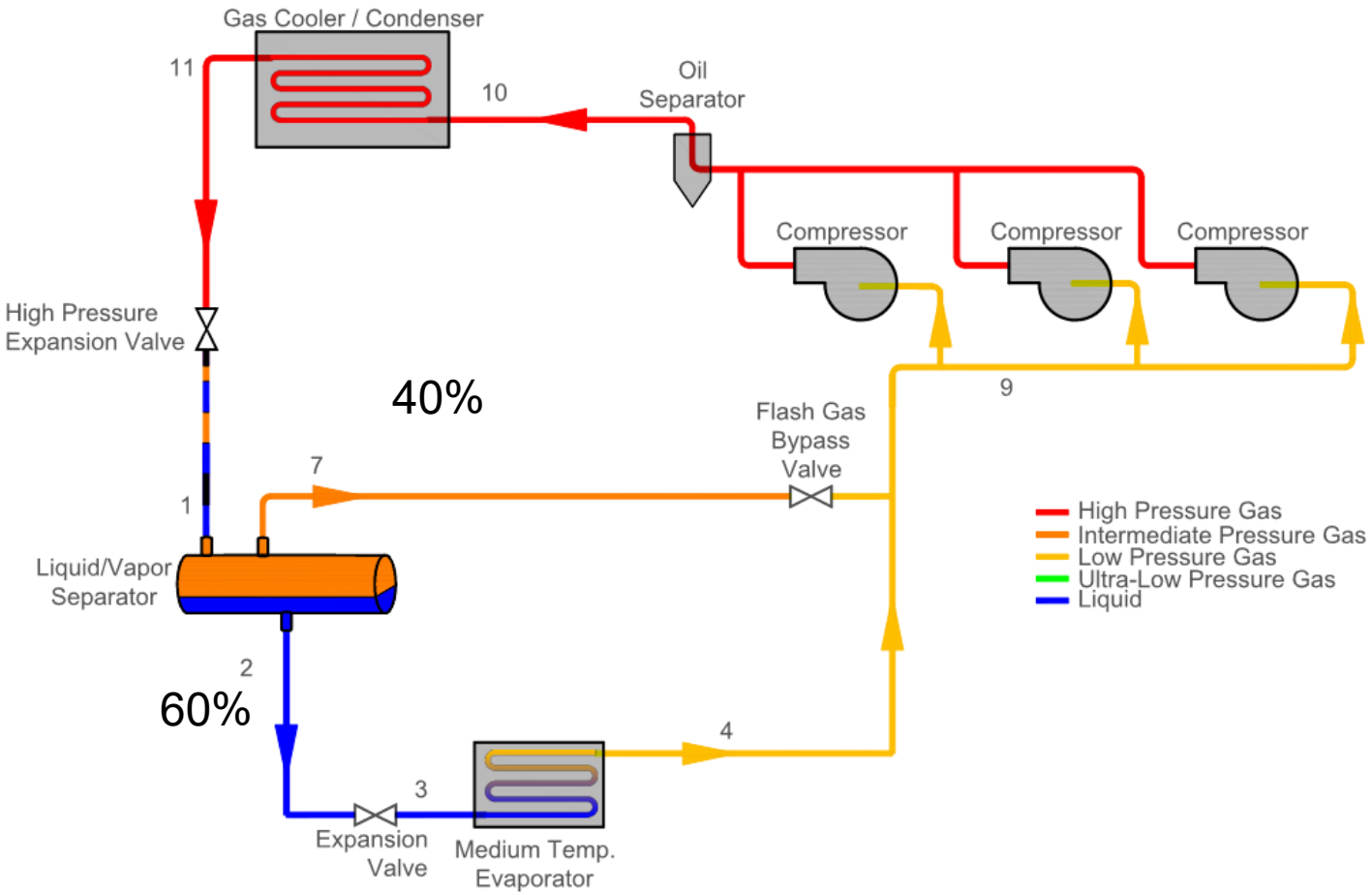
CO_2 Refrigeration System



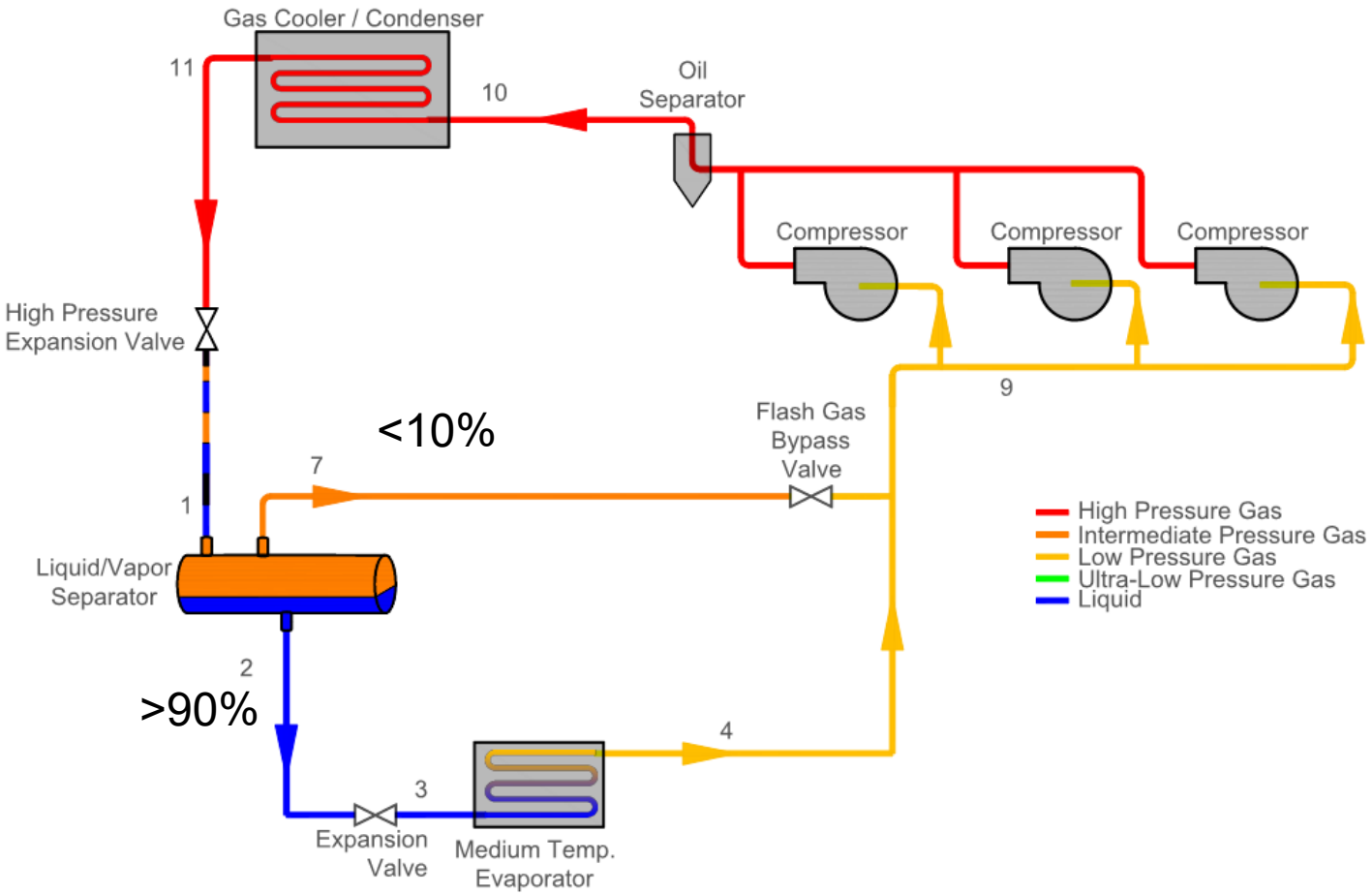
Medium Temp CO_2



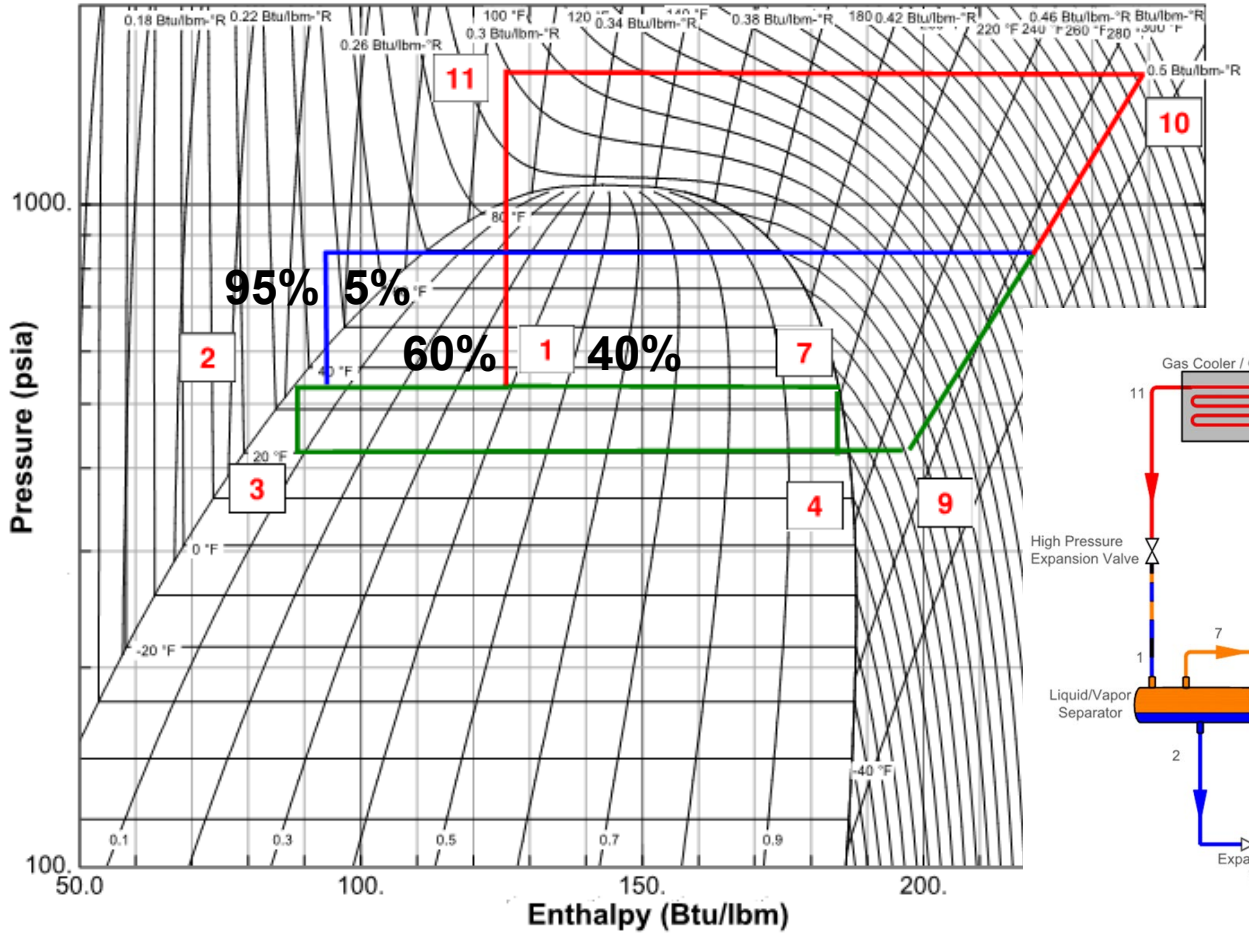
Transcritical

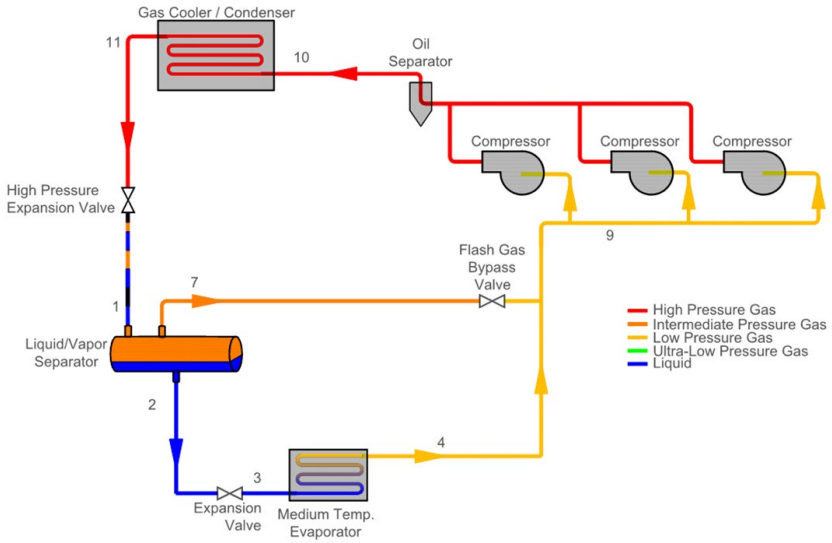


Subcritical



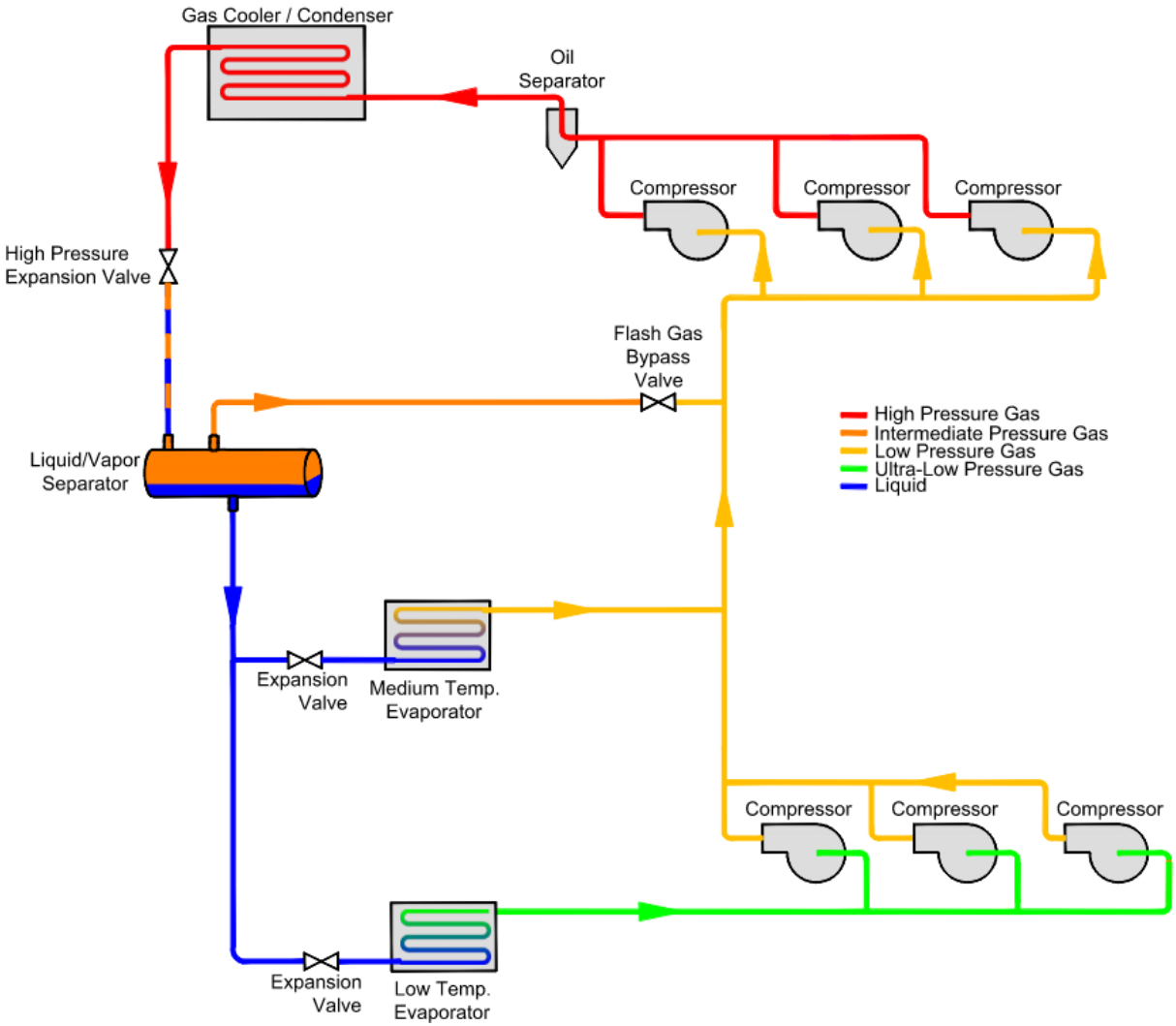
Transcritical/Subcritical



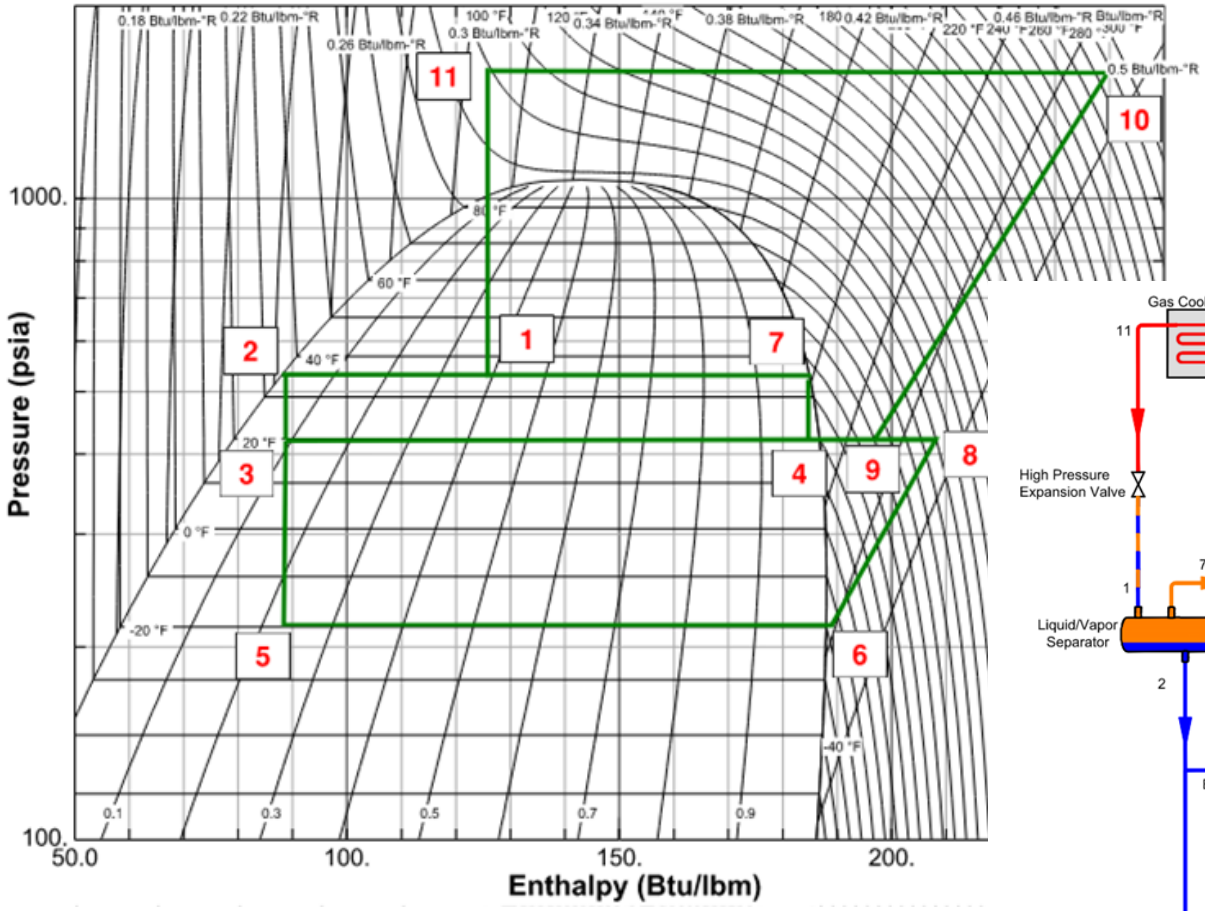


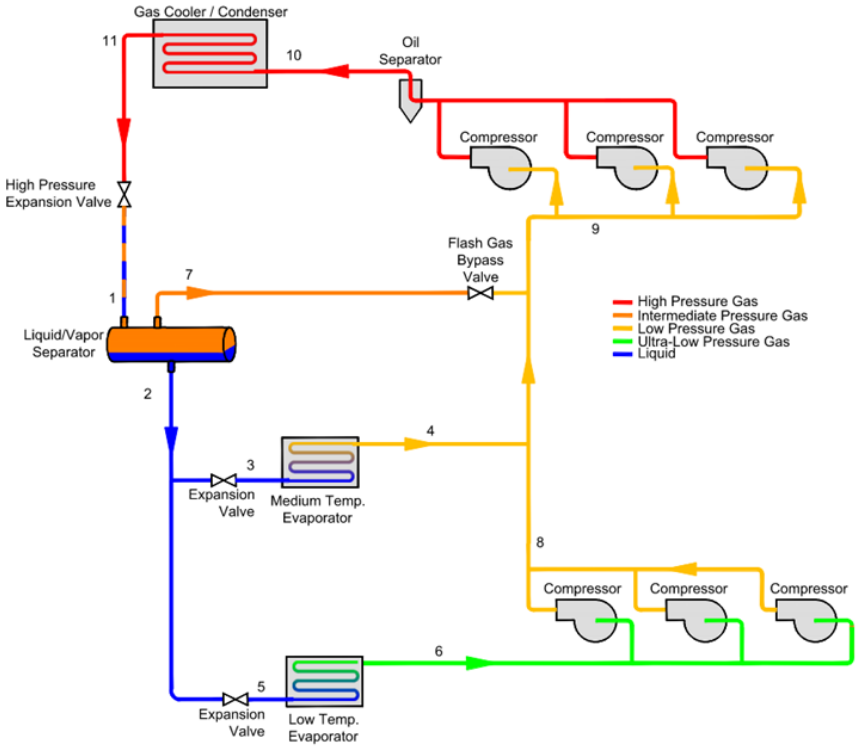
Btu = British thermal unit
Lbm = pound mass
PSIA = average atmospheric surface pressure

Transcritical Booster

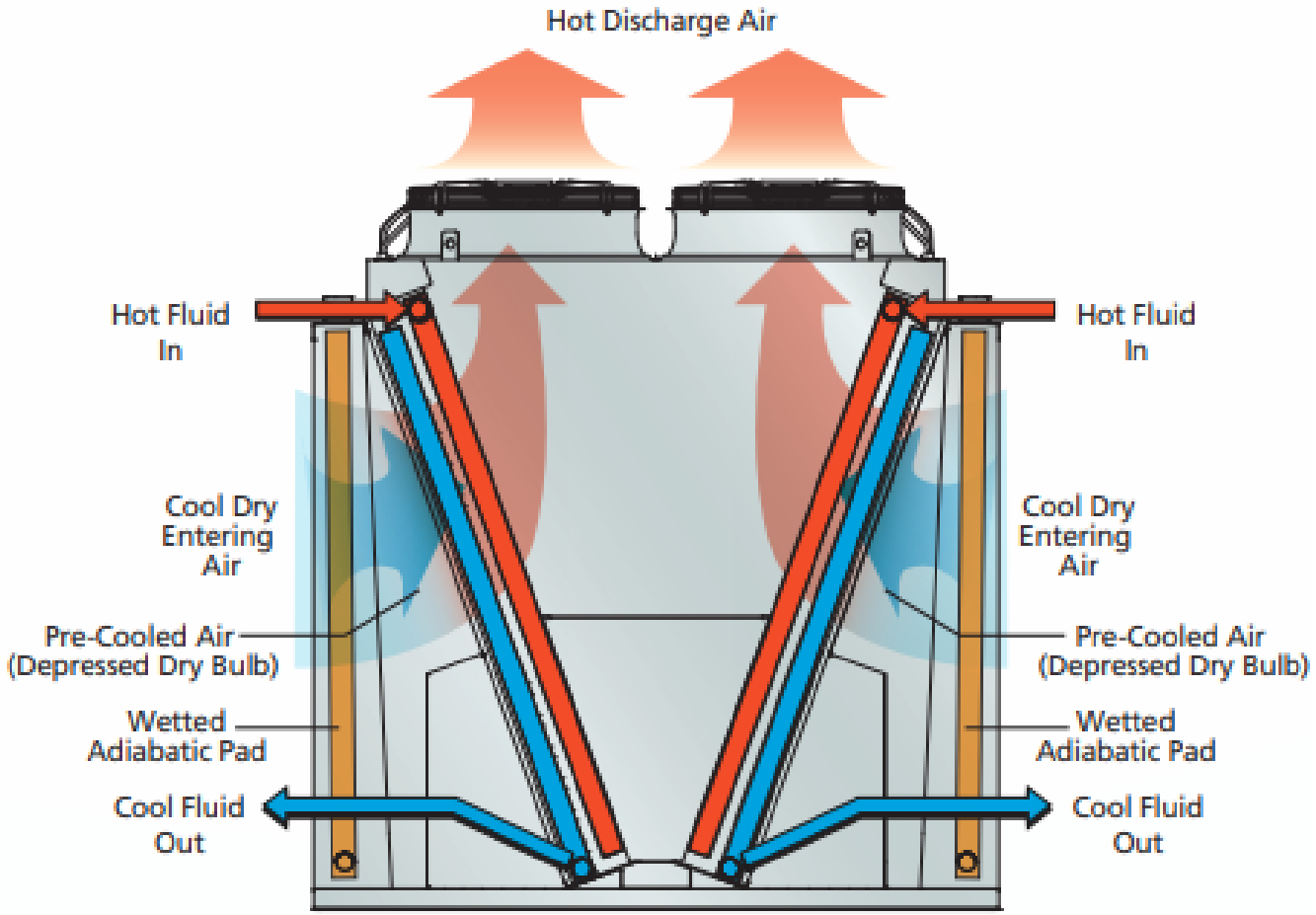


Transcritial Booster



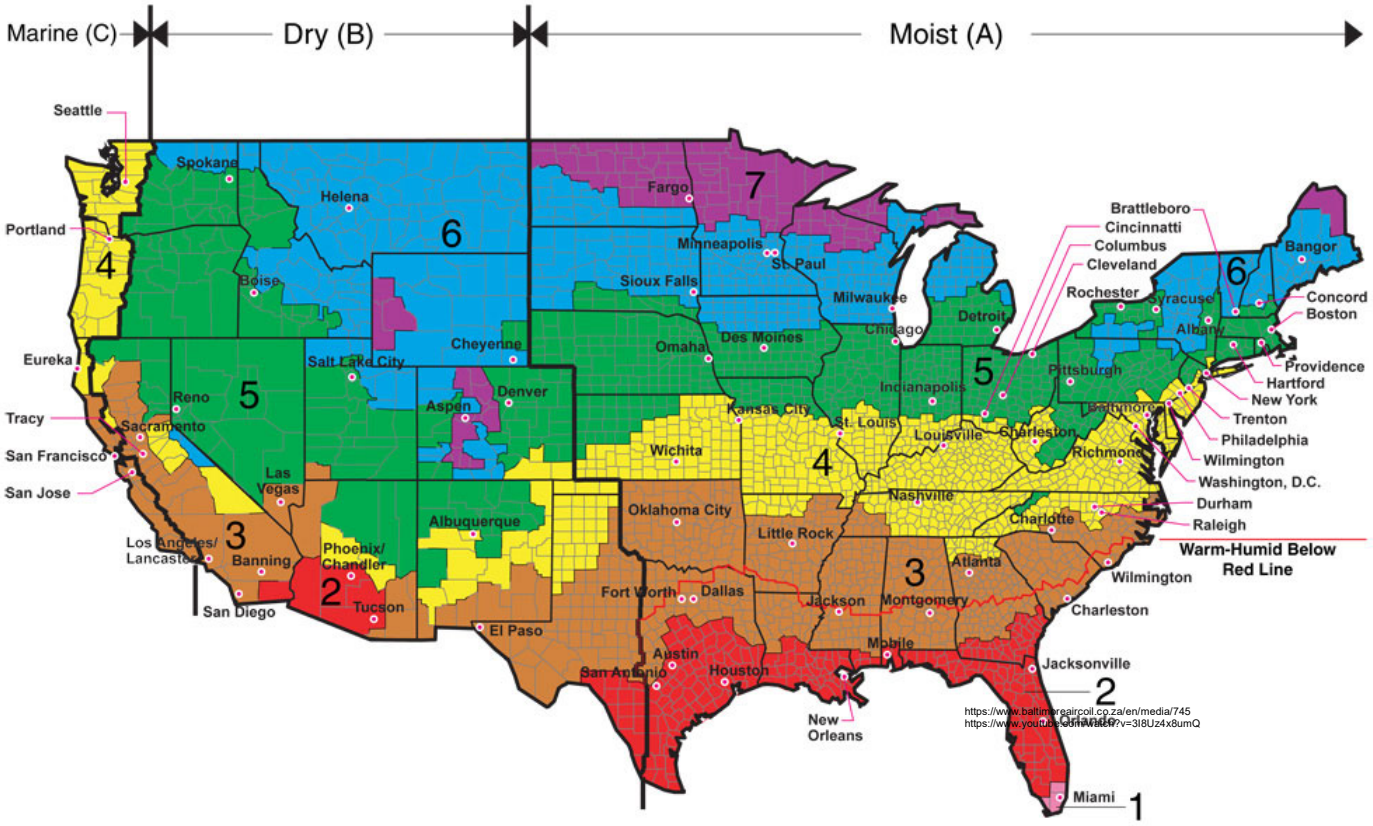


Adiabatic Gas Cooler



Adiabatic Gas Cooler – Key Benefits

- Reduces air temp entering condenser/gas cooler
- CO_2 remains in subcritical range longer or more hours a year



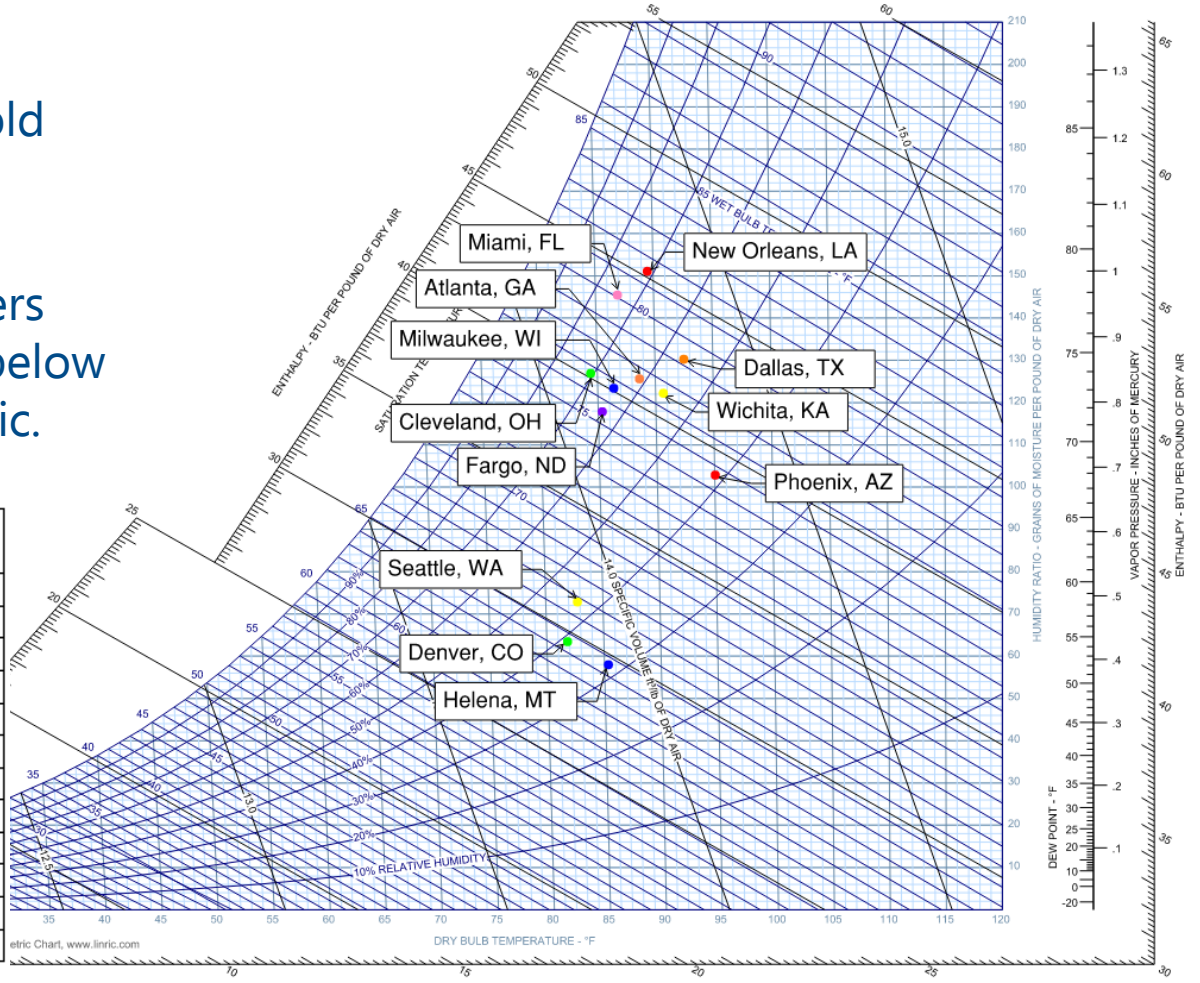
All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

Adiabatic Gas Cooler – Region Specific

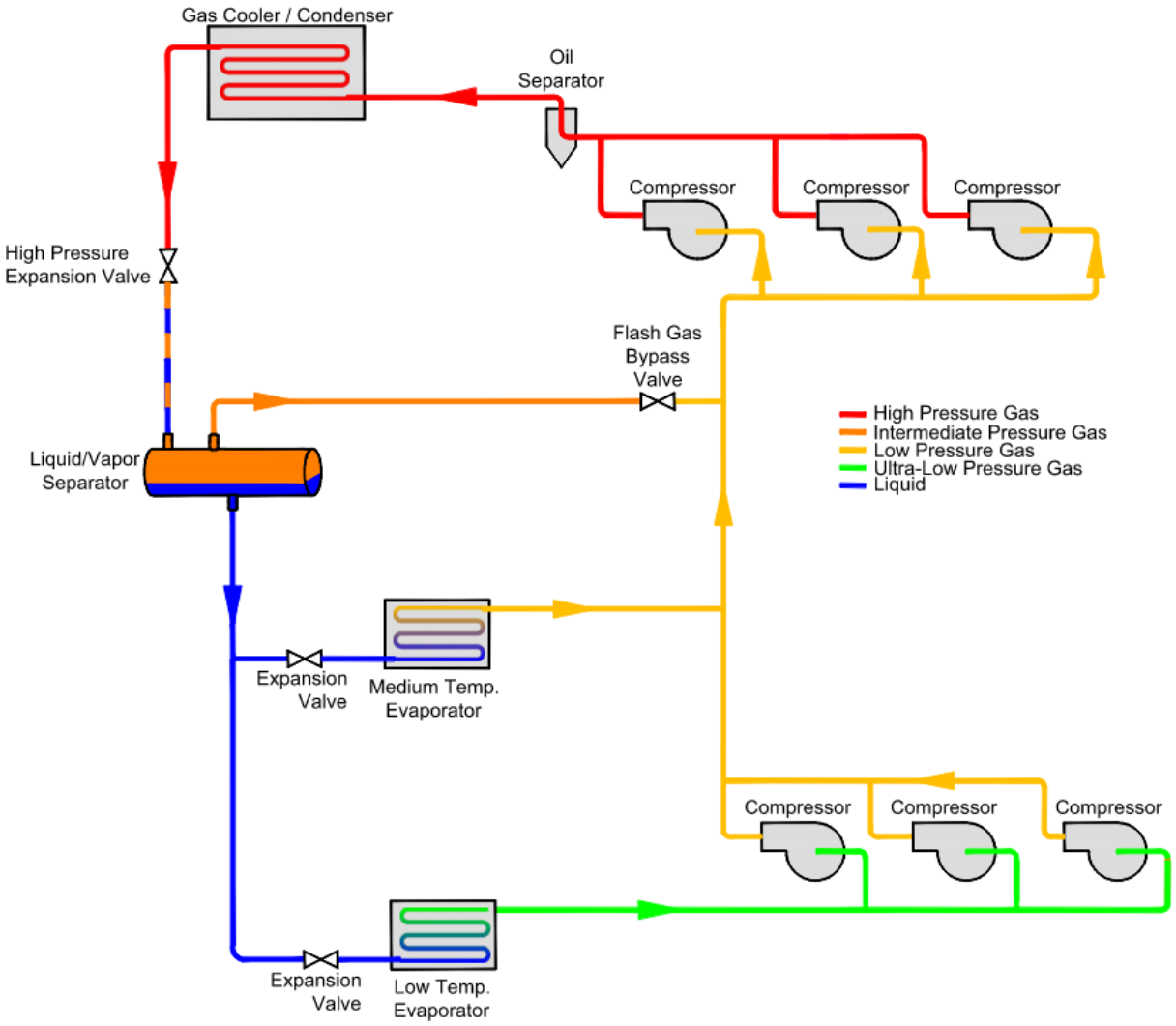
- Ideal use for an adiabatic cooler is a dry/hot region
- Regions typically more cold and humid benefit less
- Some regions may never become transcritical, others may not be able to cool below critical point with adiabatic.

City, State	Wet Bulb °F	MC Dry Bulb °F	ASHRAE Climate Zone Color
Fargo, ND	75.4	85.3	Purple
Helena, MT	64.4	85.2	Blue
Milwaukee, WI	76.6	86.4	Blue
Cleveland, Ohio	76.4	84.4	Green
Denver, CO	64.5	81.8	Green
Wichita, KA	77.6	90.7	Yellow
Seattle, WA	66.8	82.7	Yellow
Atlanta, GA	77.4	88.4	Orange
Dallas, TX	79.1	92.6	Orange
Phoenix, AZ	75.7	95.0	Red
New Orleans, LA	81.4	89.7	Red
Miami, FL	80.3	86.9	Pink

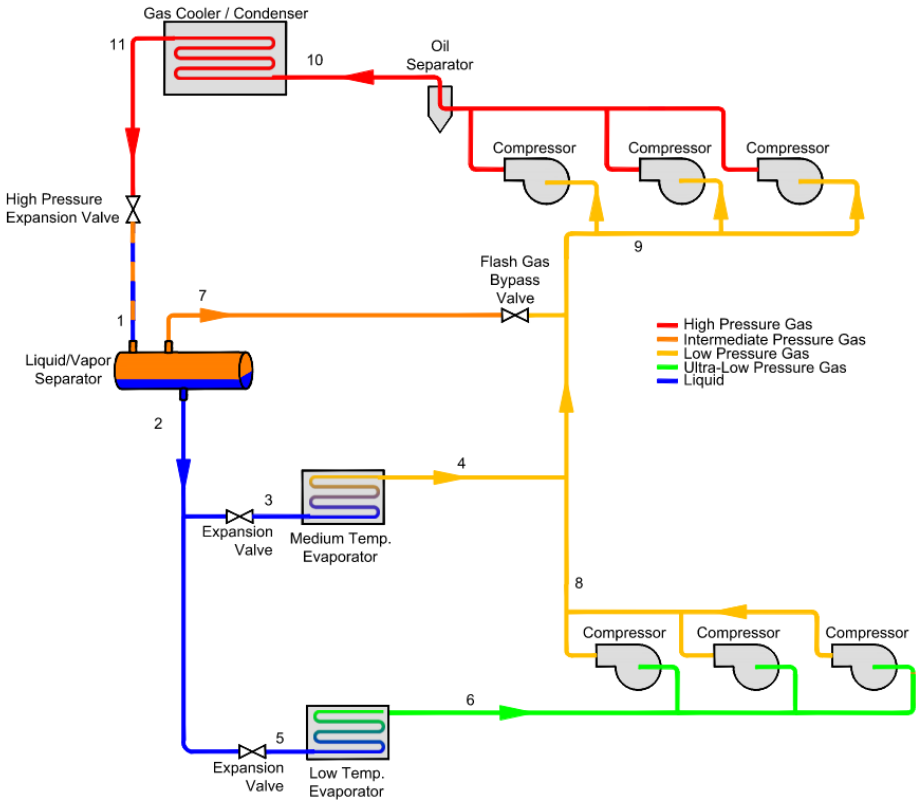


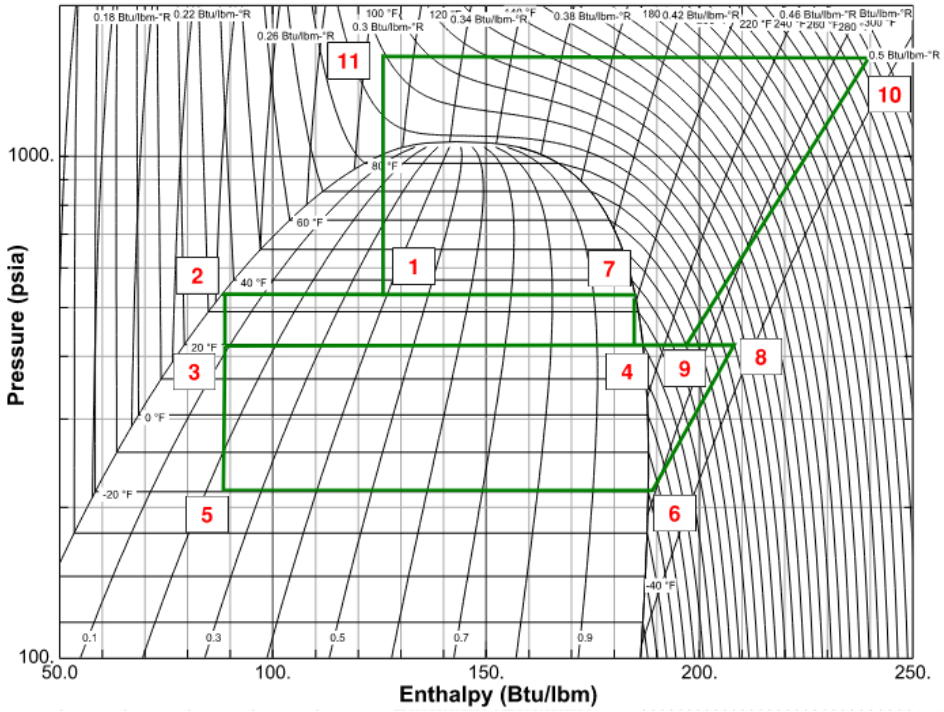
ASHRAE = The American Society of Heating, Refrigerating and Air-Conditioning Engineers
F = Fahrenheit

Without Parallel Compression



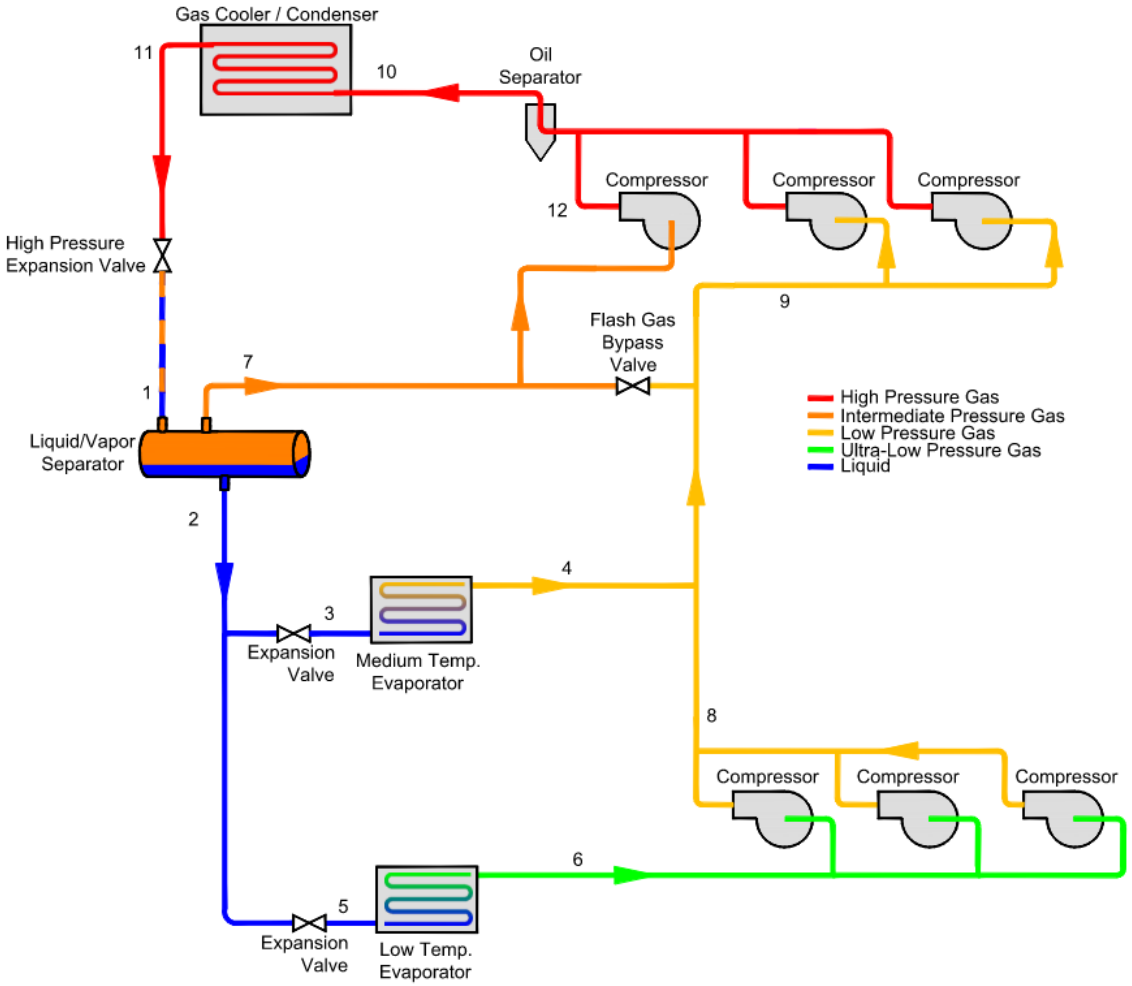
Without Parallel Compression



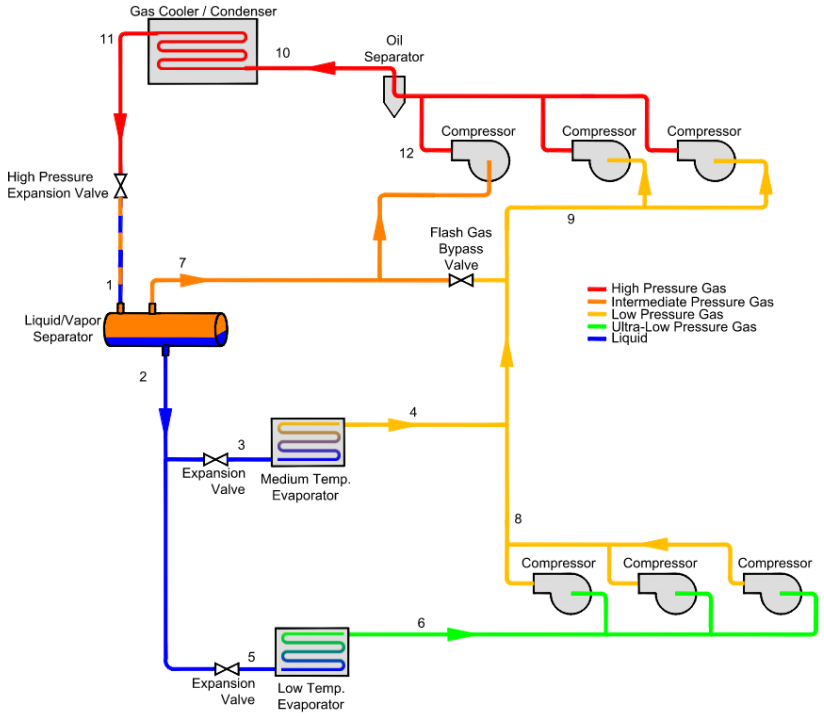


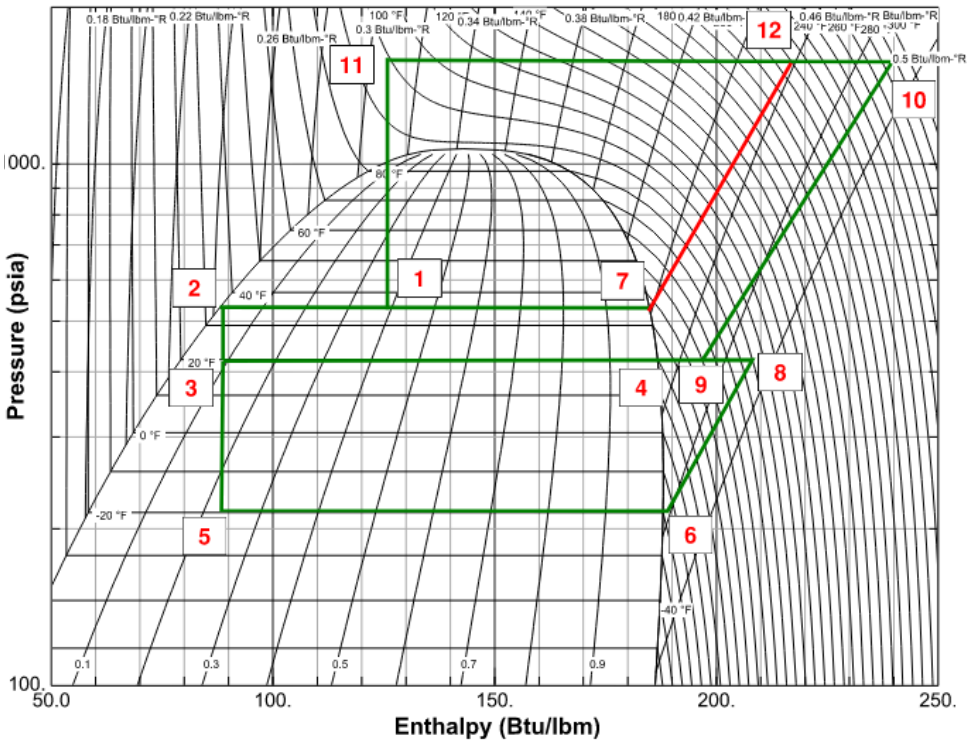
Fluid from Gas Cooler after Expansion = 60% Liquid, 40% Gas

Parallel Compression



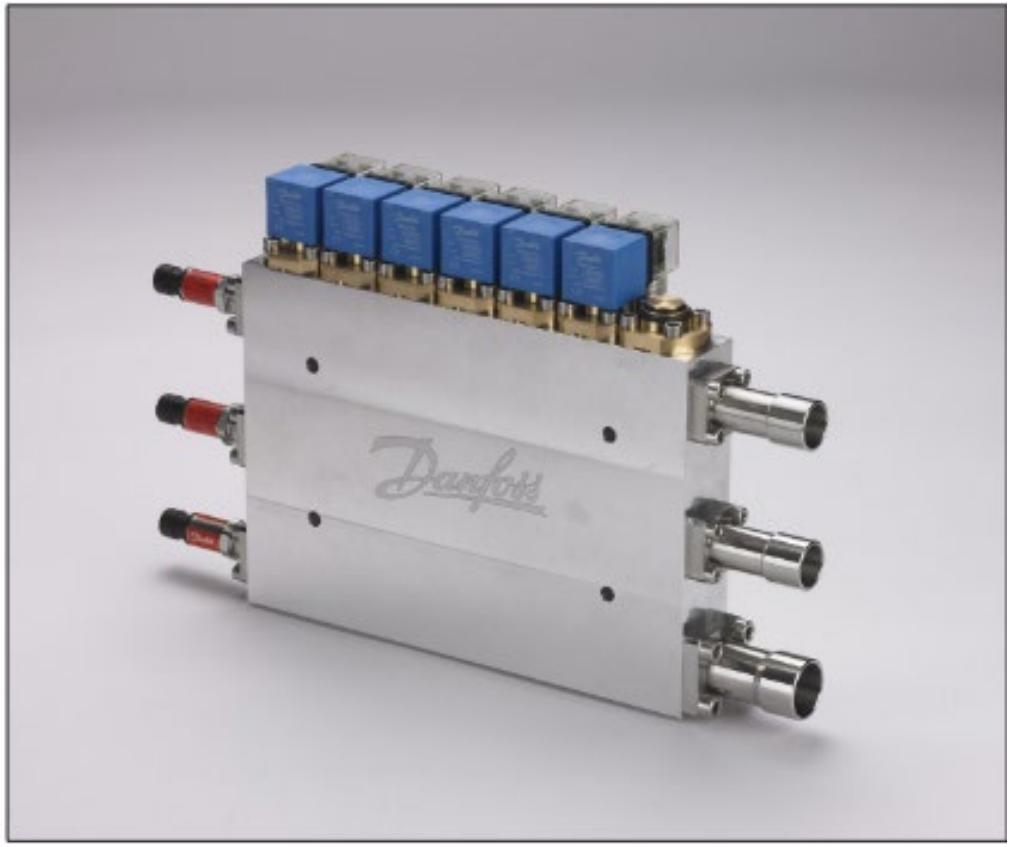
Parallel Compression





Flash Gas Compressor(s) – higher suction temperature, lower compression ratio, lower discharge temperature, less total system horsepower, more efficient

Ejectors

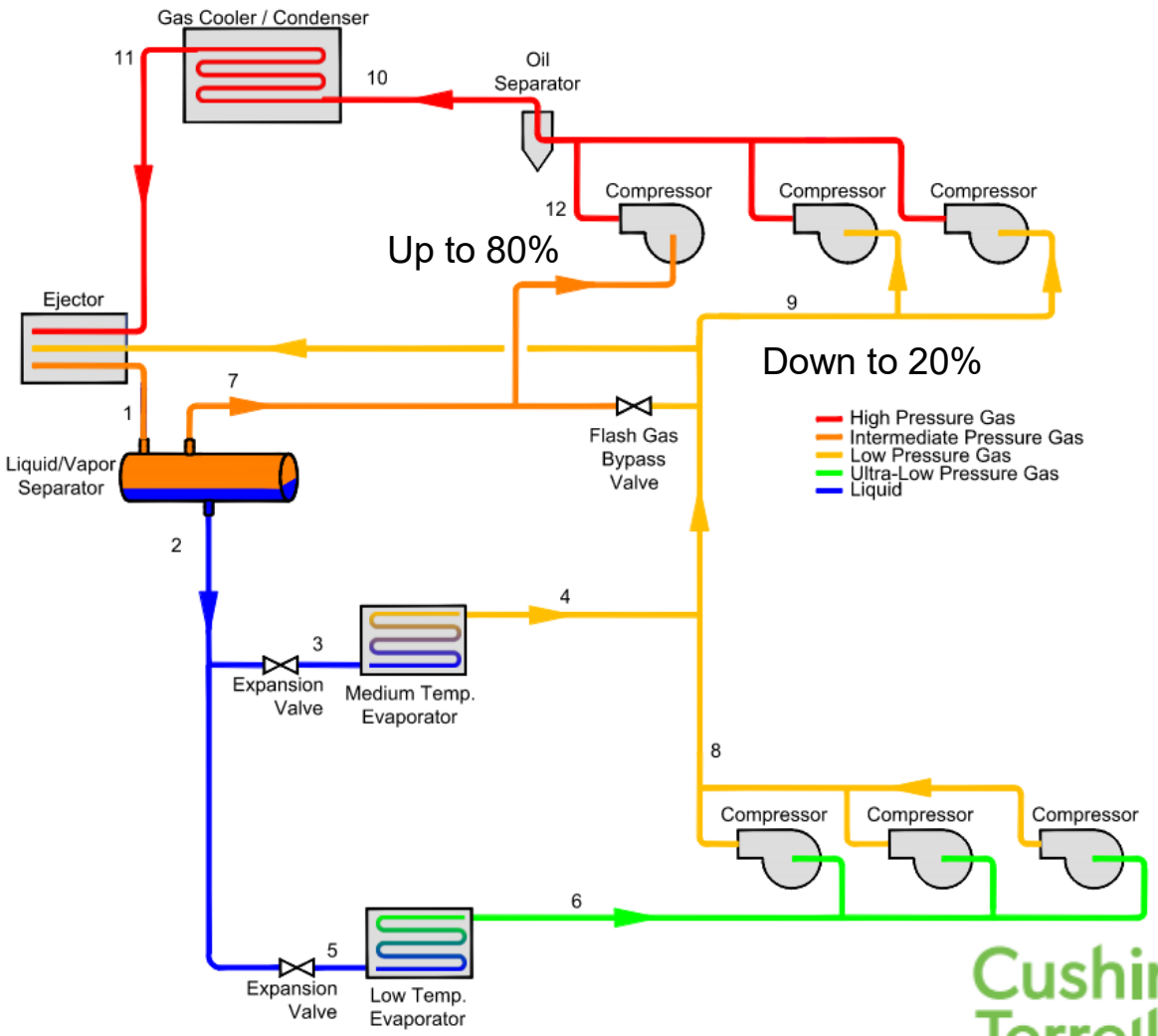


Example Ejector – Multi Ejector from Danfoss

Ejectors - Function

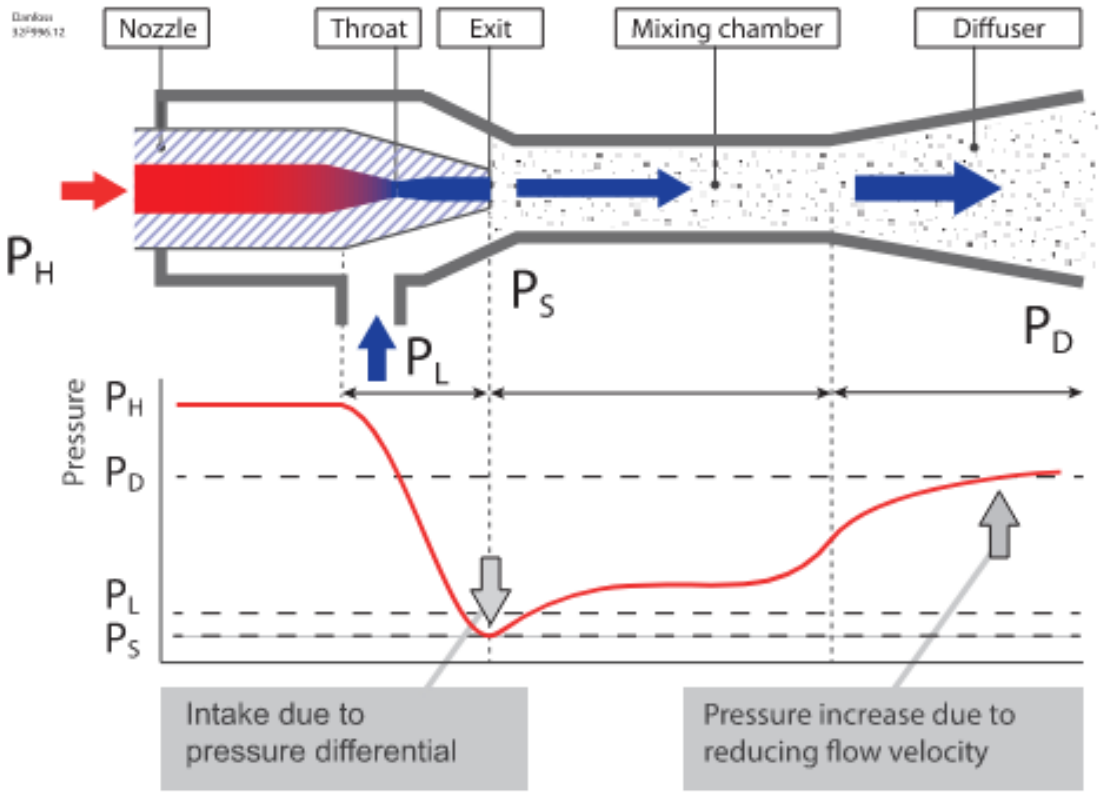
Ejector installed at gas cooler outlet, with additional connection to medium temperature suction line

Portion of medium temperature (MT) suctio elevated to flash gas pressure, compressed by higher suction group system



Ejectors - Method

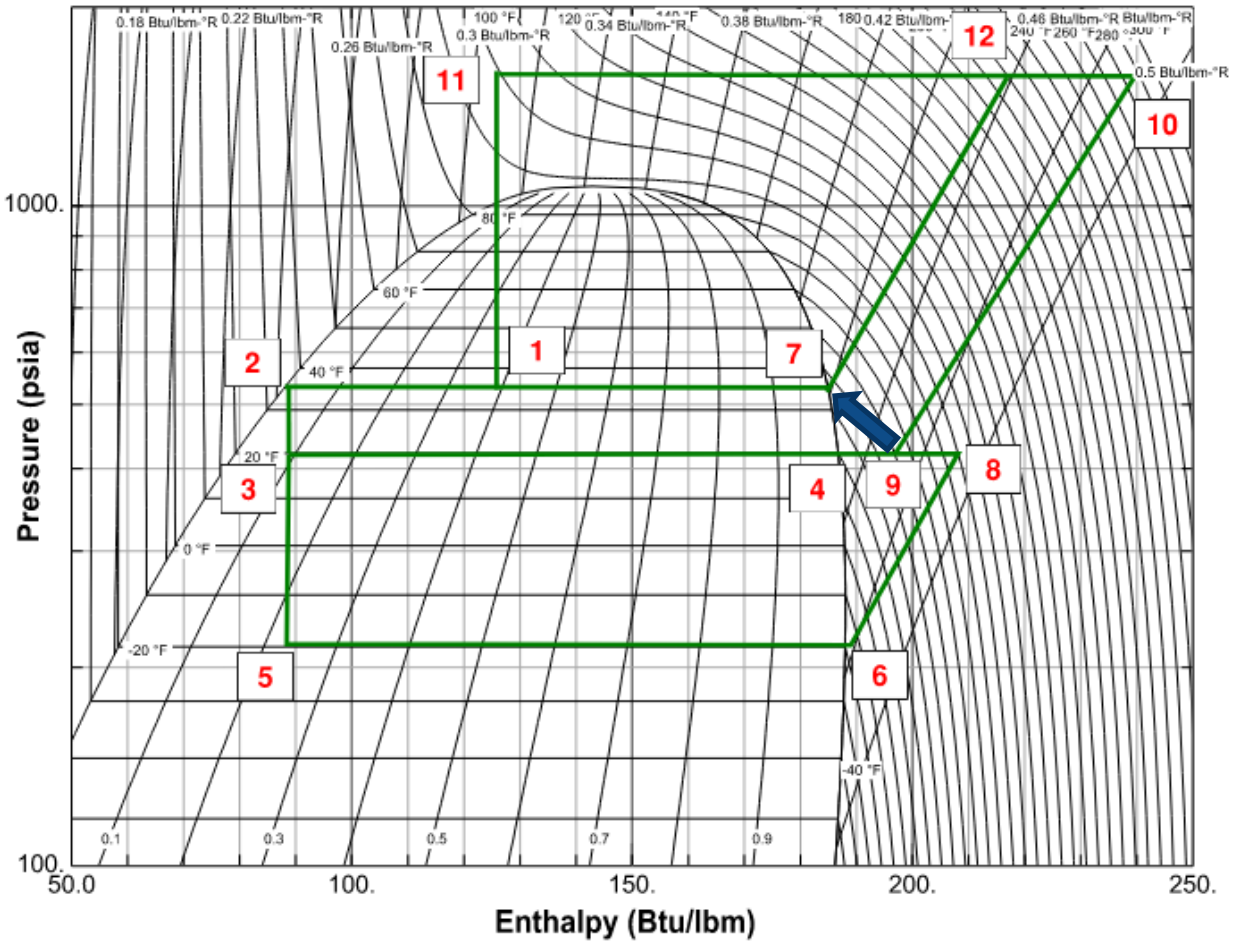
Danfoss Ejector Graphic



High pressure fluid forced through nozzle to increase velocity, resulting drop in pressure allows MT suction gas to be pulled into stream. Kinetic energy is then converted back to intermediate pressure.

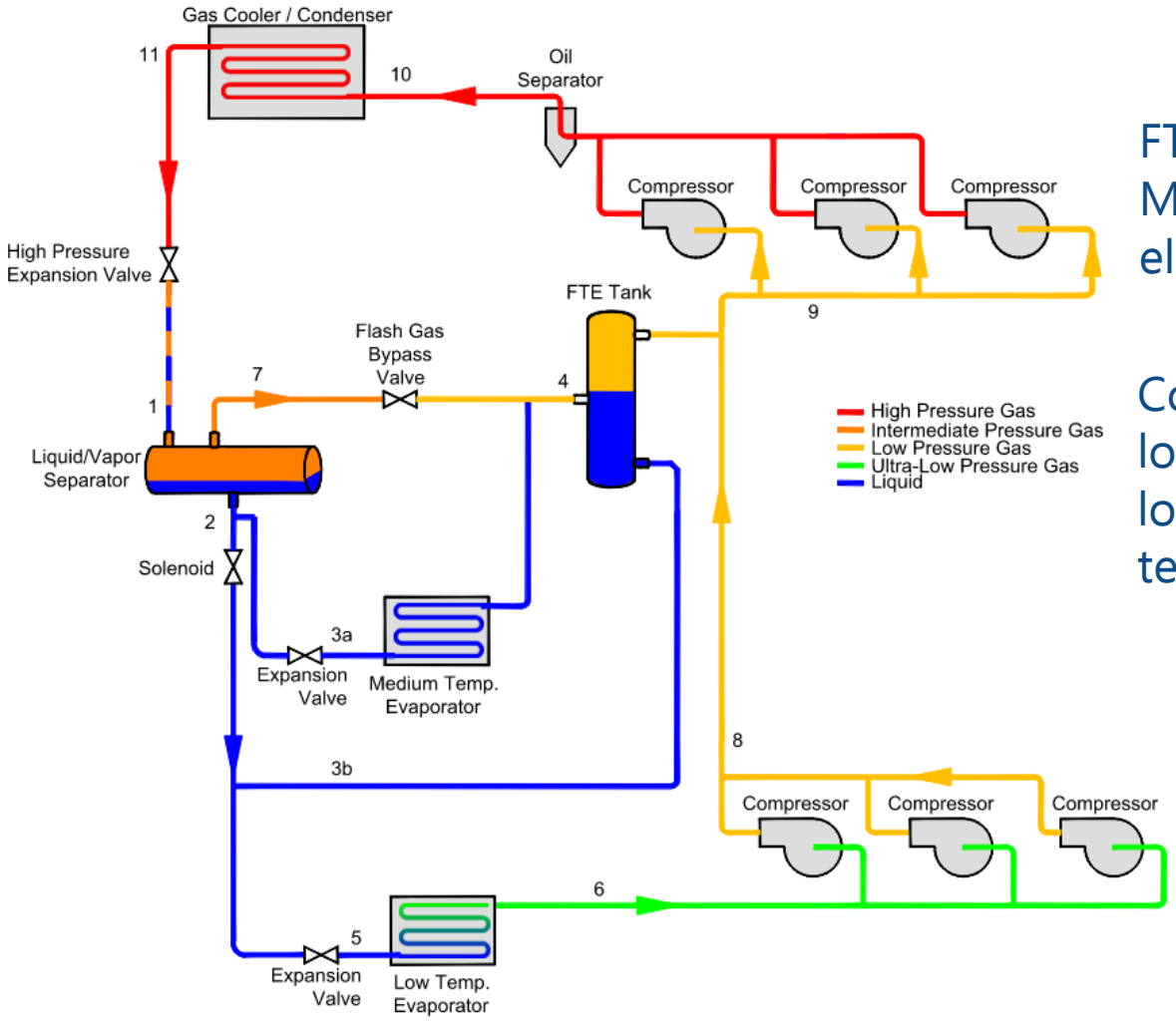
P_H: Gas Cooler Outlet Pressure
P_L: MT Suction Pressure
P_D: Diffuser (Ejector outlet) pressure

Ejectors – PH diagram



Portion of MT suction gets to "skip the line" up to more efficient compression process

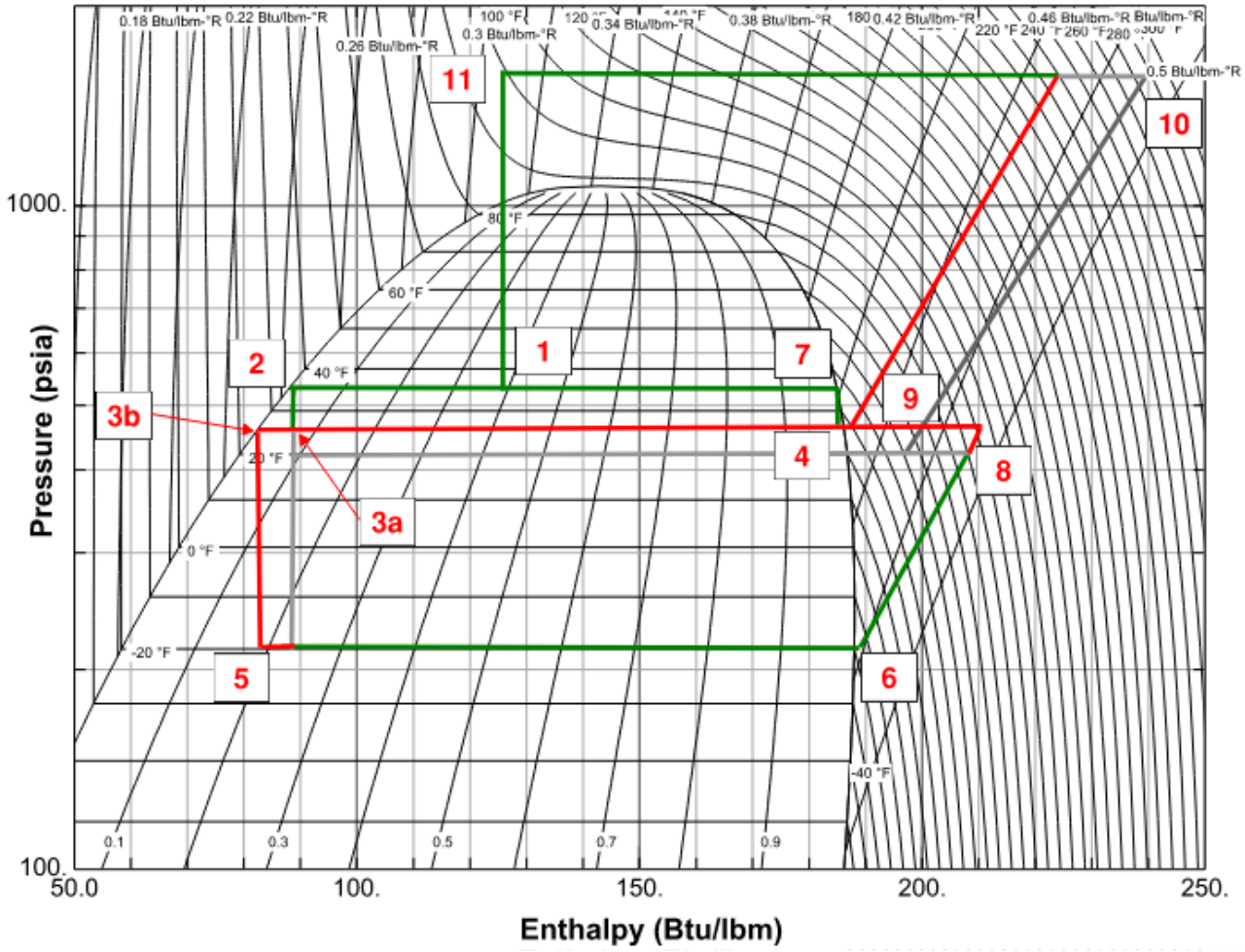
Full Transcritical Efficiency



FTE tank allows flooded MT evaporators at elevated suction pressure

Collected liquid is fed to low temperature (LT) loads at lower temperature

Full Transcritical Efficiency

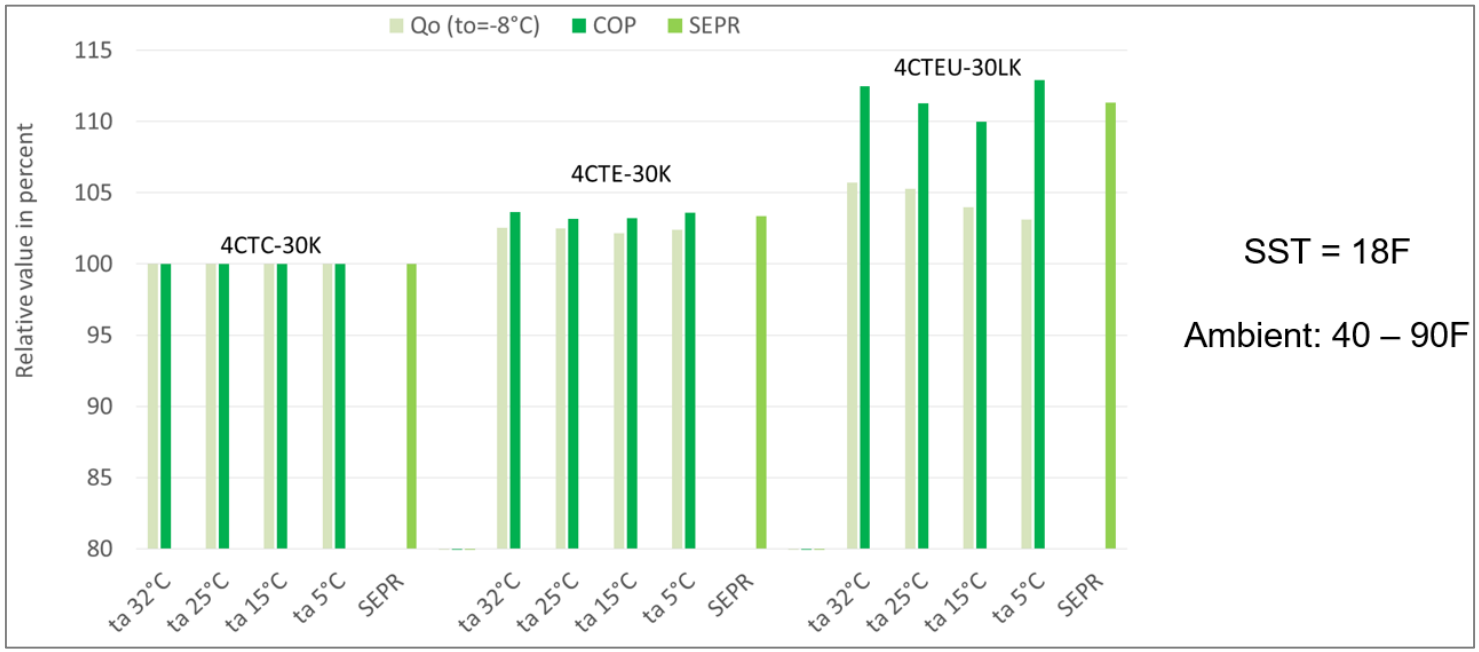


Flooded Evaporators = higher suction pressure, lower discharge pressure

Liquid collected from MT evaporators and flash gas fed to LT evaporators at lower temperature

Other Strategies

- Improved Compressor Technologies
  - Optimized
  - Unloading Technologies
  - LSPM (Line Start Permanent Magnet)



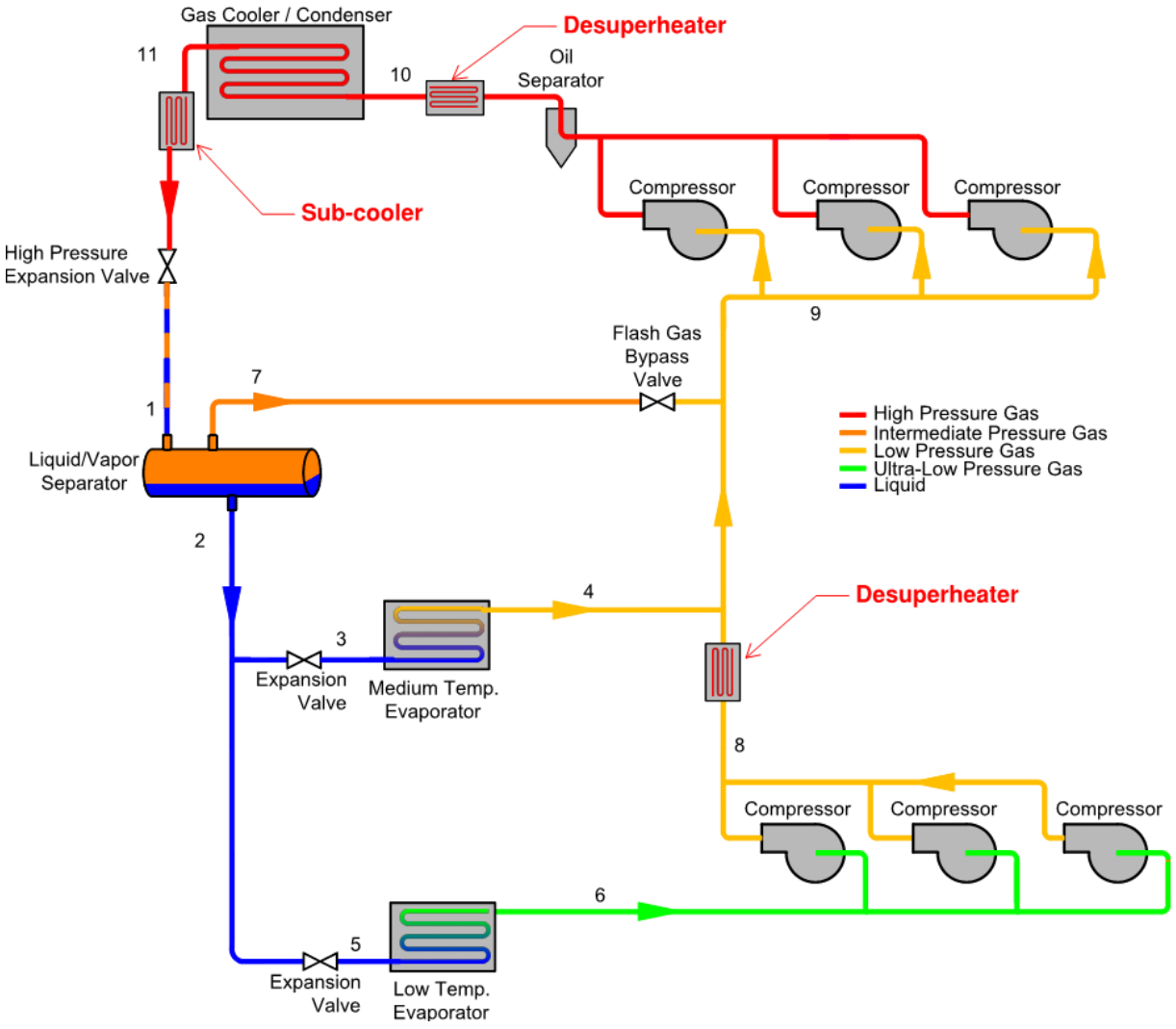
COP = coefficient of performance
SERP = Season Energy Performance Ratio

SST = saturated suction temperature
Qo = cooling capacity

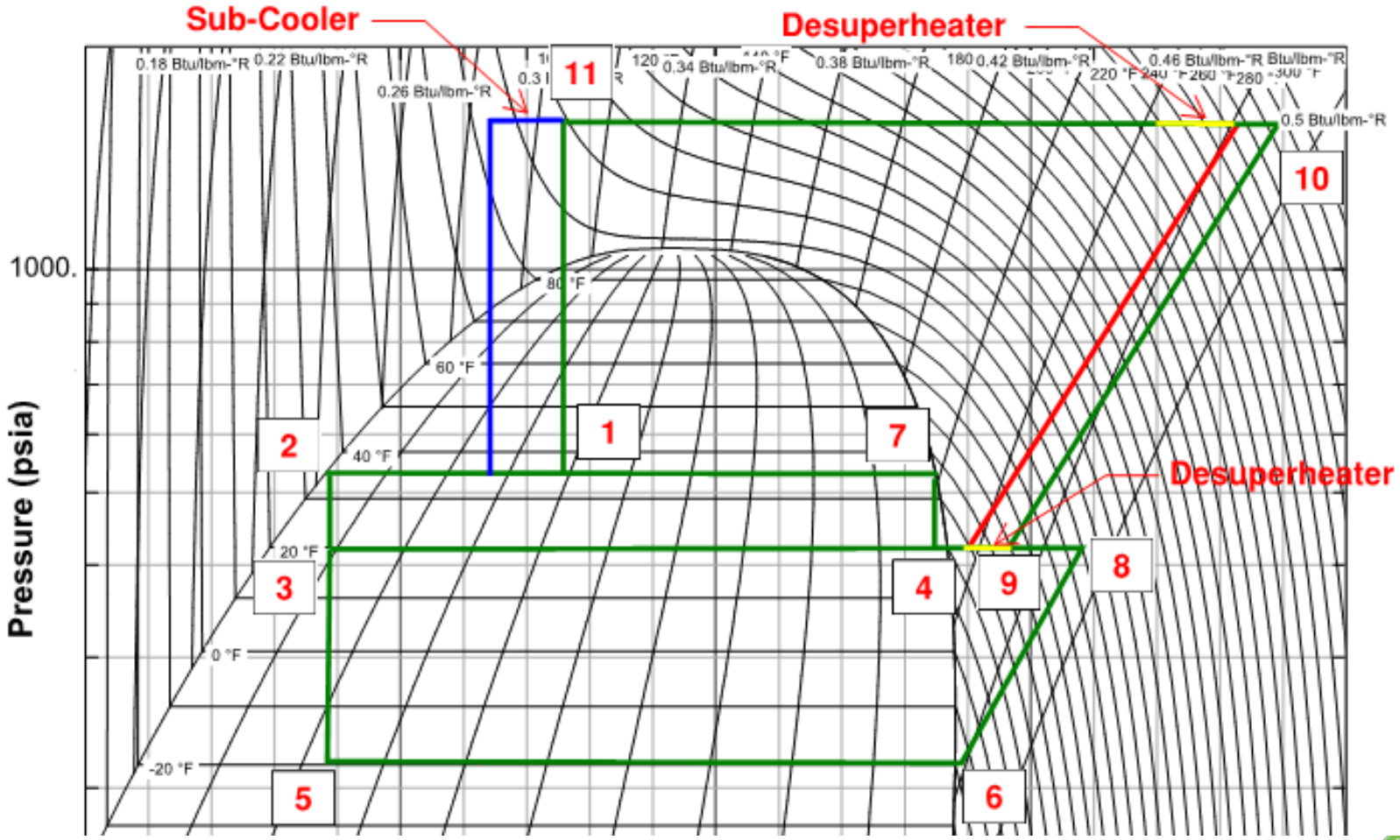
Other Strategies

- Defrost Strategies
- Desuperheating
  - Heat Reclaim
  - Air Cooled
- Subcooling
  - Traditional
  - Gas Bypass
  - ETE (Extreme Temperature Efficiency)

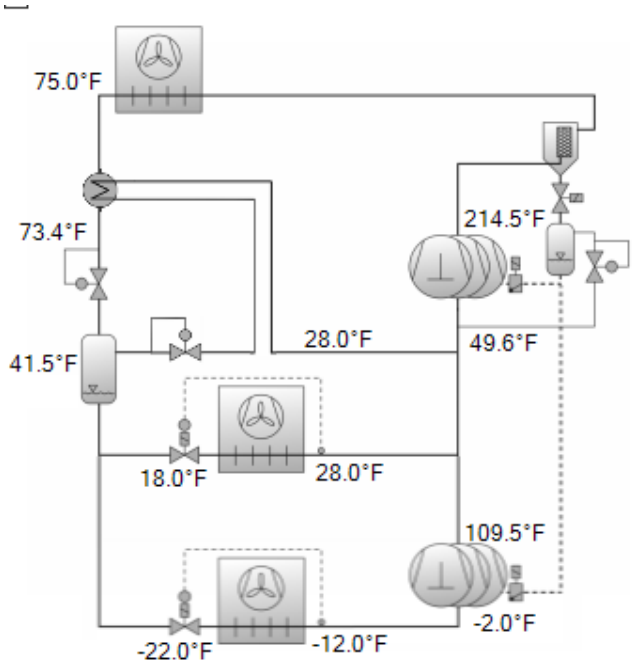
Other Strategies

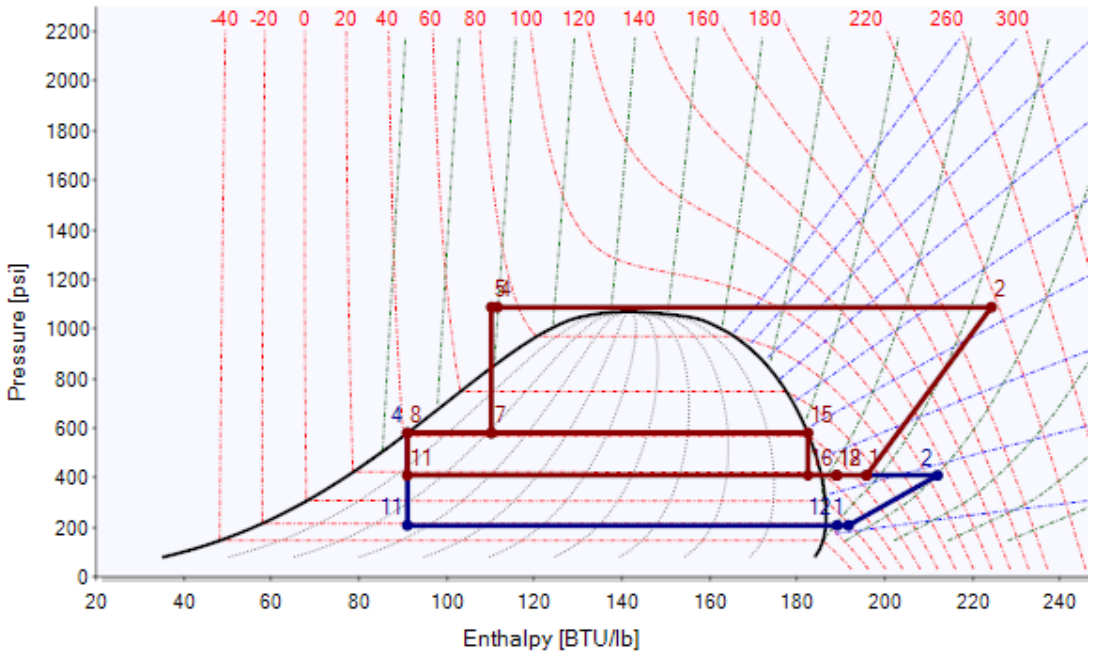


Sub-Cooling and Desuperheating

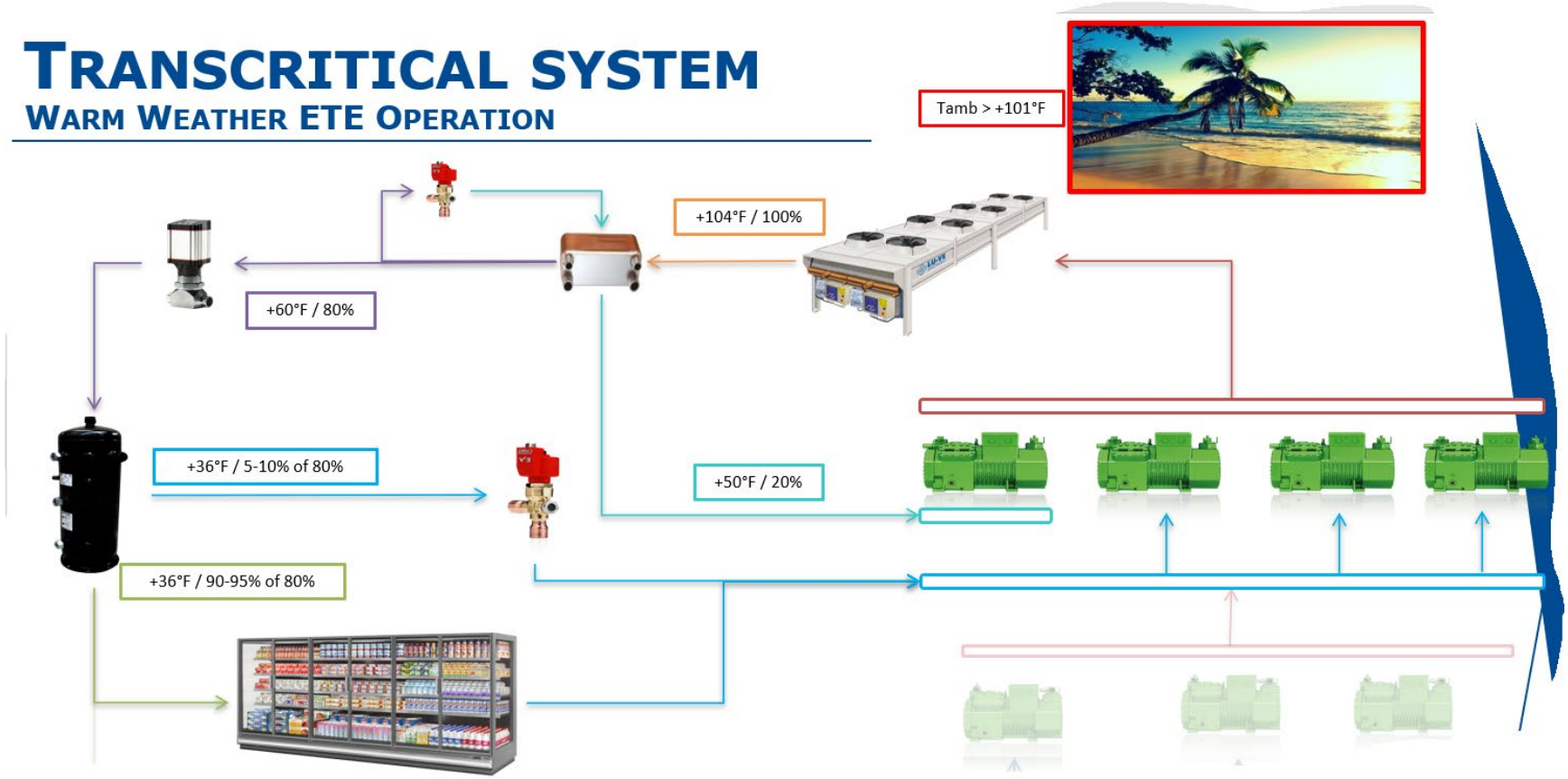


Sub-Cooling


75.0°F
73.4°F
41.5°F
214.5°F
28.0°F
49.6°F
18.0°F
28.0°F
109.5°F
-22.0°F
-12.0°F
-2.0°F

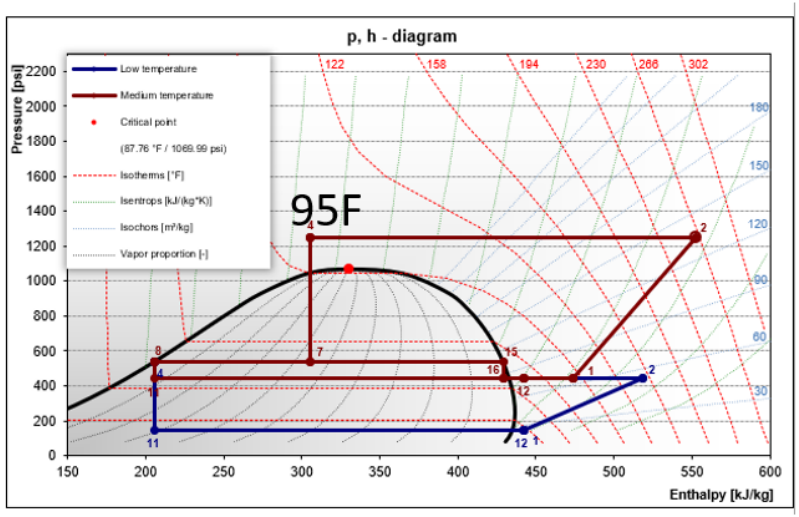

Pressure [psi]
Enthalpy [BTU/lb]
-40 -20 0 20 40 60 80 100 120 140 160 180 220 260 300
2200 2000 1800 1600 1400 1200 1000 800 600 400 200 0
20 40 60 80 100 120 140 160 180 200 220 240

Sub-Cooling

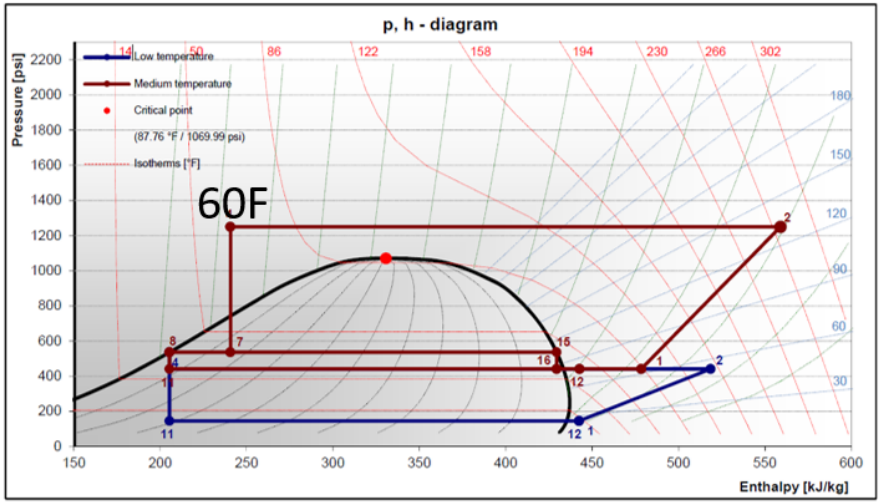

TRANSCRITICAL SYSTEM
WARM WEATHER ETE OPERATION
Tamb > +101°F
+104°F / 100%
+60°F / 80%
+36°F / 5-10% of 80%
+50°F / 20%
+36°F / 90-95% of 80%

Sub-Cooling

Summer conditions / warm climate
Standard CO2 operation system



Summer conditions/ warm climate
CO2 - ETE operation system



Reference Videos

- TheEngineeringMindset
  - https://www.youtube.com/watch?v=3I8Uz4x8umQ
- Heating, Ventilation, and Air Conditioning (HVAC) School
  - https://www.youtube.com/watch?v=rzf36okfiSM

Contacts and Upcoming Webinars

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