March 10, 2016 – San Joaquin Valley RETA Meeting

Refrigerant Selection

Peter Thomas, P.E., CSP – Resource Compliance, Inc.

Background and History

Simple, dangerous Compounds → **Safer, more complex refrigerants**

Halocarbons

- Chlorofluorocarbons
- Hydrochlorofluorocarbons
- Hydrofluorocarbons

Refrigerant + Refrigerant

=

Azeotrope/Zeotrope

Refrigeration Selection Factors

- Saturated Operating Pressures/Temperatures
- Discharge Temperatures
- Equipment Costs
- Refrigerant Cost and Availability
- Safety
- Environmental Concerns and Regulations

Saturated Operating Pressures

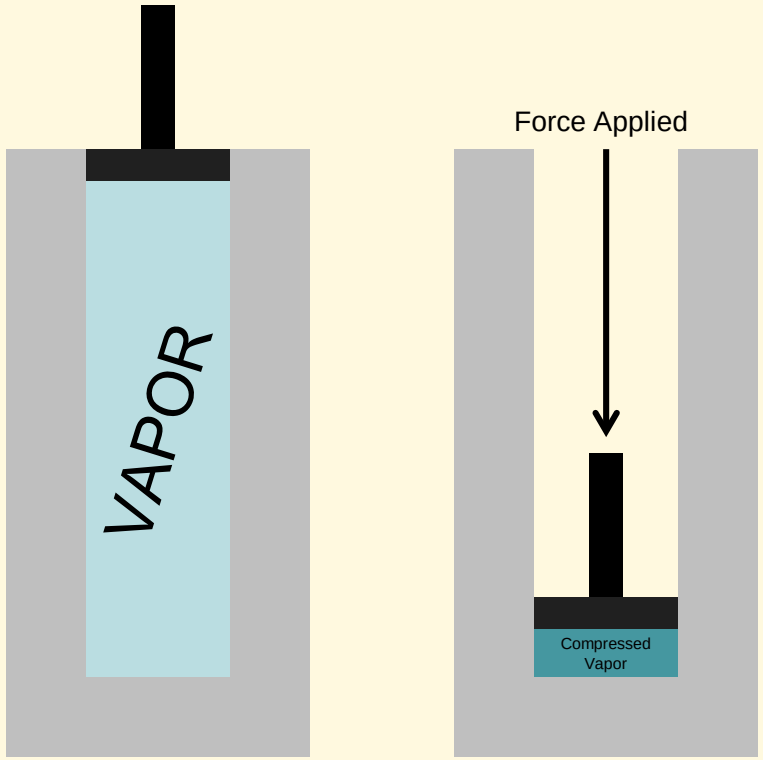
Higher Cond / Lower Evap Pressures  $↑

Evaporator Pressure > Atmosphere Pressure

Refrigerant	Evap/Disch Temp (ºF)	Evap Pressure (PSIG)	Cond Pressure (PSIG)
HCFC-22	10/95 20/85	32.38 43.29	181.83 155.94
CFC-11	10/95 20/85	3.4 inHg 4.39 inHG	6.80 3.20
CFC-12	10/95 20/85	14.83 21.20	108.30 91.76
CFC-500	10/95 20/85	19.70 37.20	130.50 110.90
HCFC-502	10/95 20/85	45.90 51.80	201.50 173.70
R-717	10/95 20/85	23.79 33.50	181.21 151.80
R-134a	10/95 20/85	11.63 18.65	114.08 95.53
R-507	10/95 20/85	46.30 59.27	226.06 195.17
R-404a	10/95 20/85	43.32 55.48	220.22 187.61

Discharge Temperature

- Heat of Compression
- Higher Discharge Temperatures cause problems and raises cost
- Reciprocating Compressors vs Screw Compressor



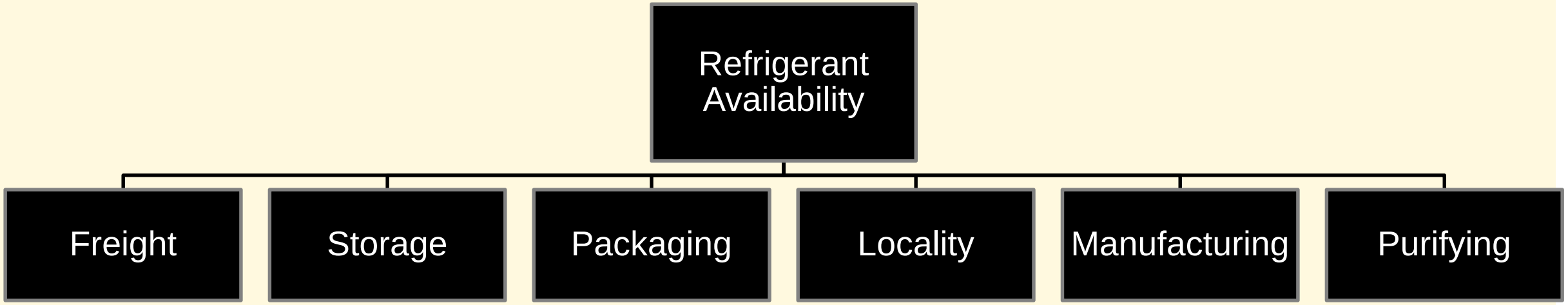
Refrigerant	Evap/Cond Temp (ºF)	Theoretical Discharge Temp (ºF)	Evap/Cond Temp (ºF)	Theoretical Discharge Temp (ºF)
HCFC-22	10/95	135.94	10/85	124.03
	20/95	130.34	20/85	116.48
CFC-12	10/95	108.85	10/85	98.34
	20/95	106.27	20/85	95.74
R-717	10/95	218.48	10/85	196.54
	20/95	197.04	20/85	176.17
R-134a	10/95	104.00	10/85	93.27
	20/95	104.34	20/85	93.49
R-507	10/95	104.27	10/85	93.49
	20/95	104.61	20/85	92.40
R-404a	10/95	104.21	10/85	92.20
	20/95	103.14	20/85	91.82

Equipment Cost

- Each refrigerant has a unique specific heat capacity and refrigerating effect
- There is a direct correlation between CFM and compressor operating cost
- CFM/Tr is a measure of the relative efficiency of the system.

Refrigerant	Temp	Refrigerating Effect (BTU/lb)	CFM/Tr
HCFC-22	10/95	67.63	3.17
	20/85	70.77	3.03
CFC-12	10/95	48.71	5.45
	20/85	51.16	5.18
HCFC-502	10/95	43.38	3.40
	20/85	46.34	3.19
R-717	10/95	465.07	3.14
	20/85	476.71	3.06
R-134a	10/95	41.13	5.74
	20/85	64.57	5.43
R-507	10/95	44.54	3.31
	20/85	48.41	3.04
R-404a	10/95	45.80	3.49
	20/85	49.90	3.21

Refrigerant Availability

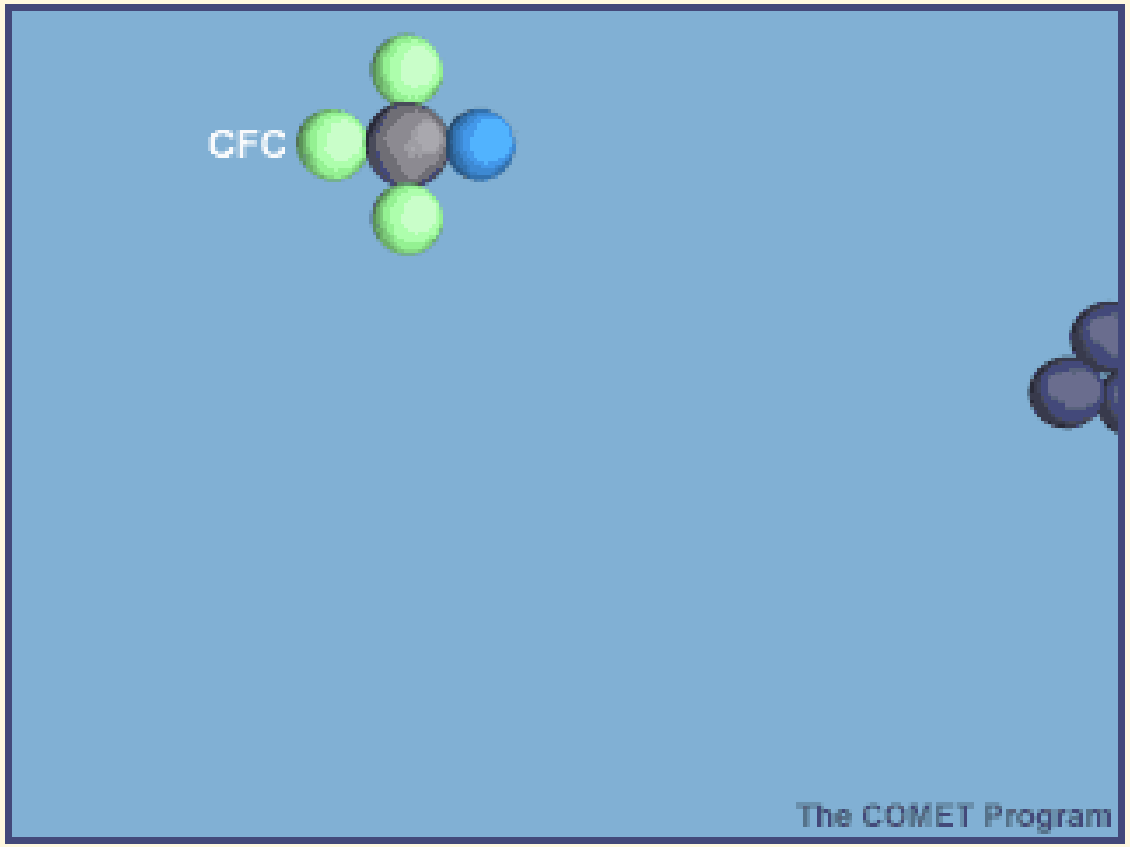


Refrigerant Safety

- How to determine how safe a refrigerant is
  - Toxic
  - Flammable
  - Self-Alerting
  - Reactive
  - First-Aid
  - PPE
- Hydrostatic Expansion
  - Liquids evaporate when heated
  - Vapors expand when heated
  - Vessels may rupture if filled too full

ODP and GWP

- **ODP** - Ozone Depletion Potential
- **GWP** - Global Warming Potential

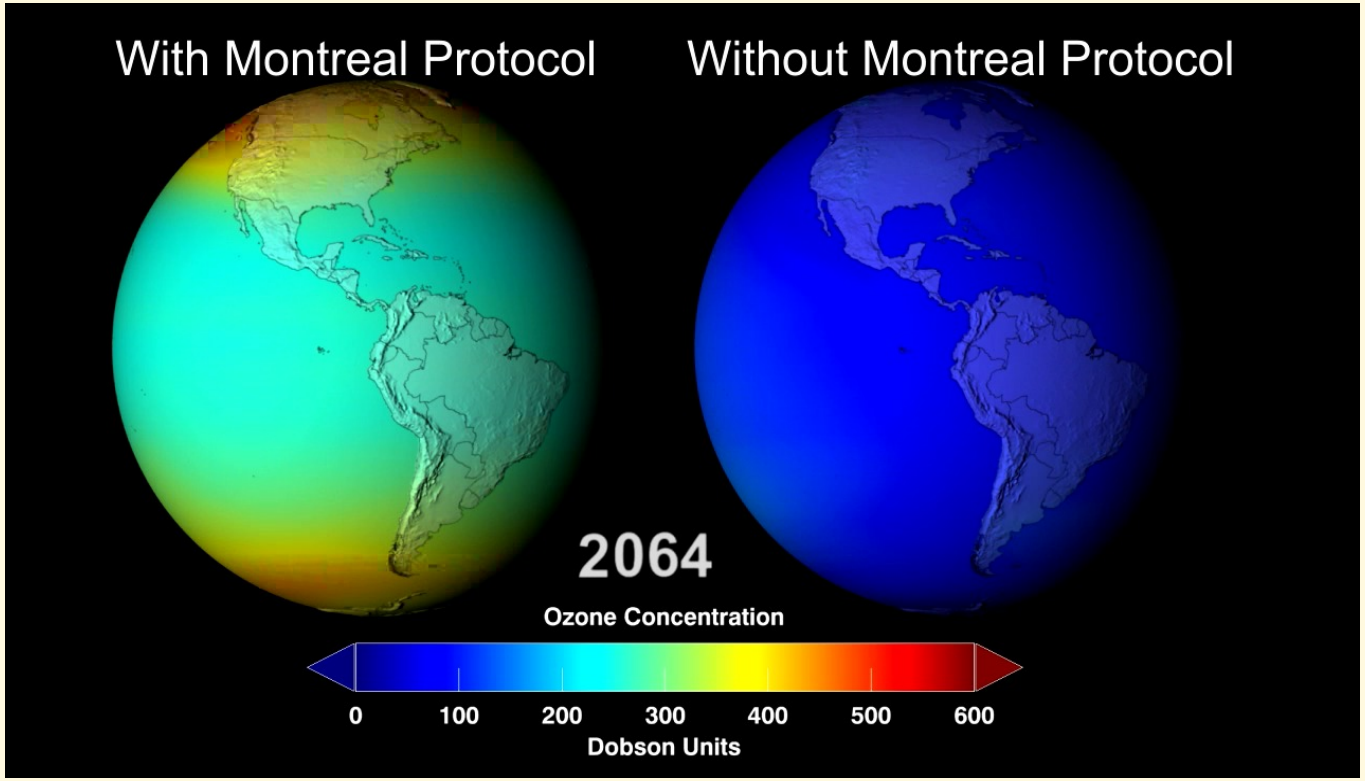


GWP of Various Refrigerants

Refrigerants	GWP
HFC-23	14,200
CFC-11	4,750
CFC-12	10,900
HCFC-22	1,790
HFC-134a	1,370
R-717	Under 1
R-500	8,100
R-404a	3,700
R-744	1

Montreal Protocol

- Formed in 1987
- Currently has been ratified by 197 parties
- Regulates high ODP refrigerants



R-22 Phaseout

- No new or imported R-22 will be allowed in the U.S. on or after Jan. 1, 2020.

R-22 Phaseout Slashes Supply to 18M Pounds

Refrigerant Phaseout, SNAP changes, and more will affect HVACR industry in 2016

REFRIGERANT RETROFIT: An HVAC technician retrofits a residential air conditioning unit from R-22 to Freon™ MO99. *Photo courtesy of the Chemours Co.*

February 8, 2016

Jen Anesi Roby

KEYWORDS Climate Action Plan / HVACR regulations / Paris Agreement / R-22 phaseout / refrigerant recovery

Reprints

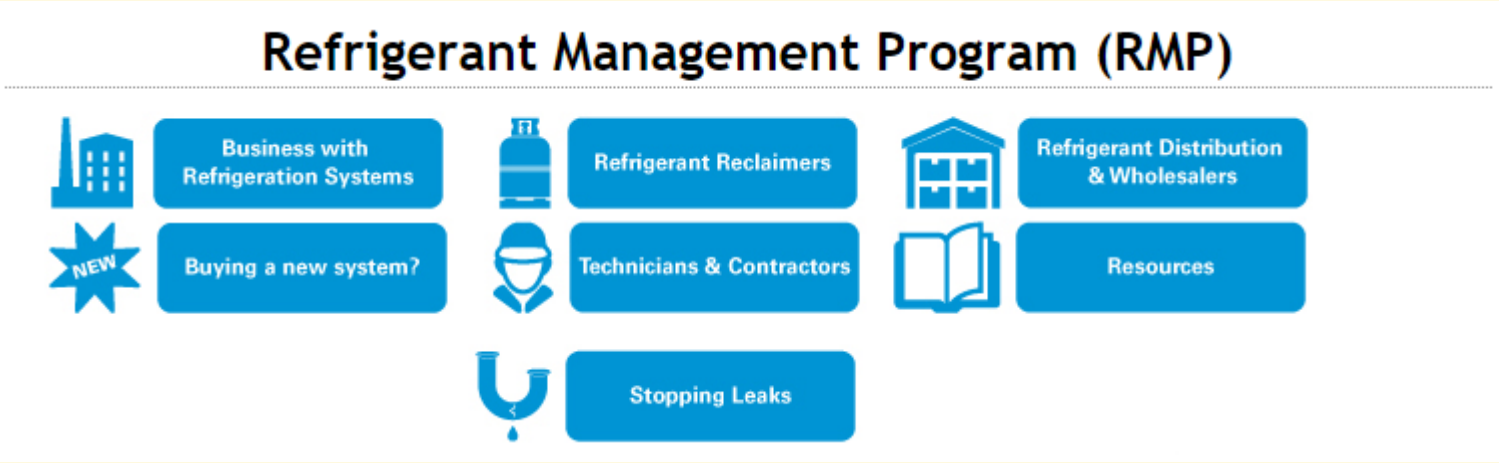
Of the dozens of regulations that have been issued the last few years, the U.S. Environmental Protection Agency's (EPA's) rule governing the production and importation of hydrochlorofluorocarbon (HCFC)-22 has had perhaps the most immediate impact on HVACR contractors. Additionally, the EPA's Significant New Alternatives Policy (SNAP) Program, Section 608 of the Clean Air Act, and President Barack Obama's Climate Action Plan have all shaped the ever-changing refrigerant landscape. And, with no signs of this regulatory action slowing, 2016 is set to be another year full of significant changes in the refrigerant market.

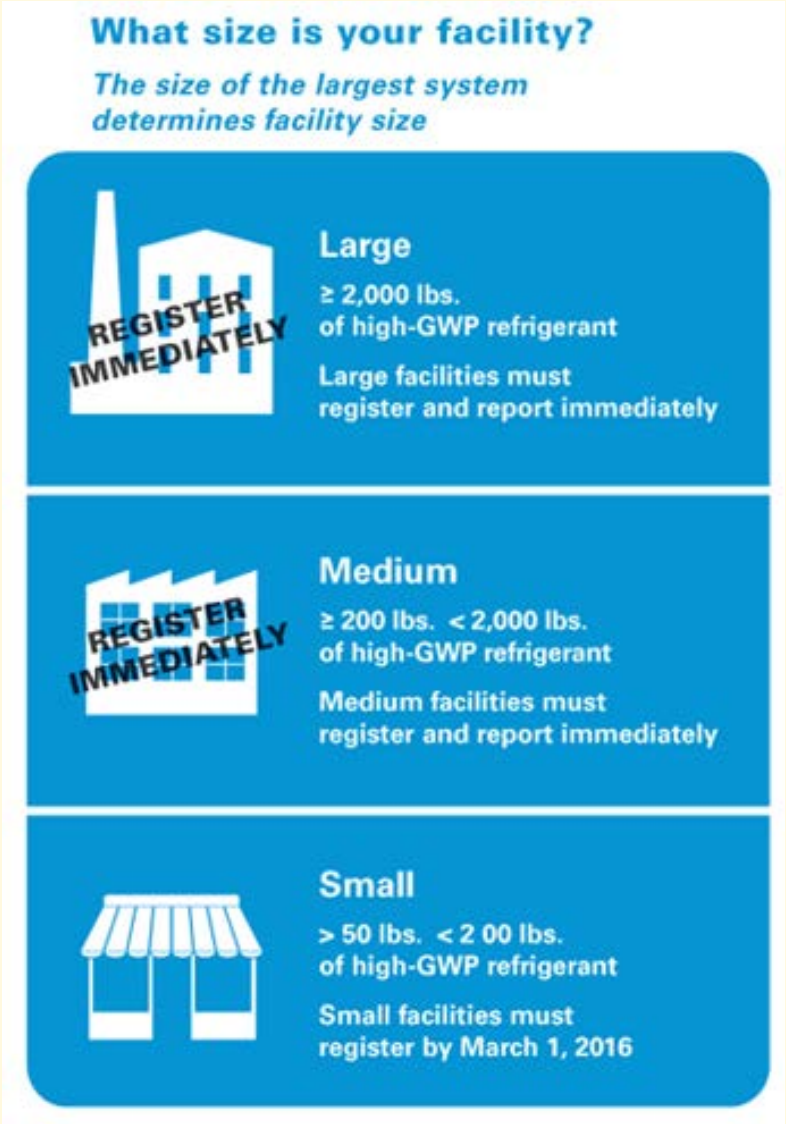
R-22 PHASEOUT CONTINUES

In October 2014, the EPA announced its final phasedown schedule regarding the production

California Air Resources Board

- **Refrigerant Management Program**
  - Registration
  - Reporting
  - Recordkeeping





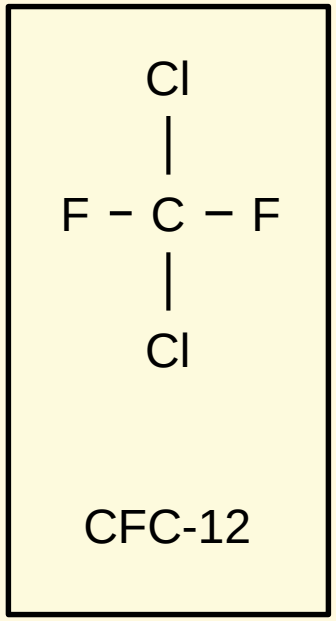
Types of Refrigerants

- CFC
- HCFC
- HFC
- Azeotropes
- Zeotropes
- Hydrocarbons
- Inorganic Compounds

Pros/Cons - CFCs

Pros	Cons	Refrigerants
•Relatively inert •Relatively low boiling points •Relatively low toxicity •Relatively low flammability •High thermal stability	•Has detrimental amounts of ODP •Significant GWP •Phased out by the Montreal Protocol •Virtually undetectable by human senses •Miscible in oil	• R-11 • R-12 • R-114 • R-115

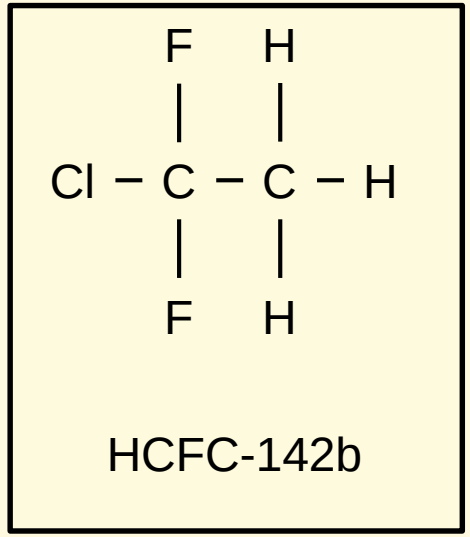
Molecular Structure



Pros/Cons - HCFCs

Pros	Cons	Refrigerants
•A lower ODP than CFCs •Relatively inert •Relatively low boiling points •Relatively low toxicity •Relatively low flammability •High thermal stability	•Has detrimental amounts of ODP •Significant GWP •Being phased out by the Montreal Protocol •Virtually undetectable by human senses •Miscible in oil	• R-22 • R-123 • R-124

Molecular Structure

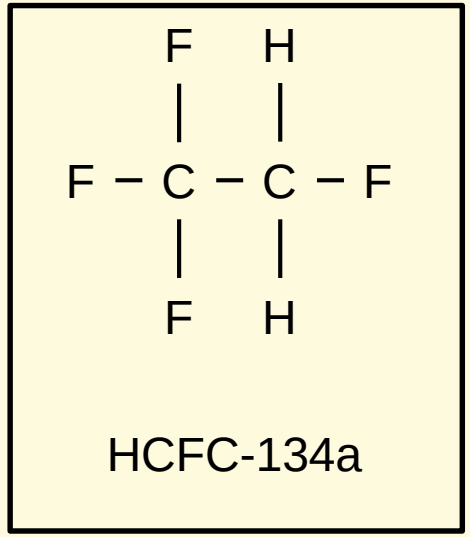


HCFC-142b

Pros/Cons - HFCs

Pros	Cons	Refrigerants
•An ODP of Zero •Relatively inert •Relatively low boiling points •Relatively low toxicity •Relatively low flammability •High thermal stability	•Possesses GWP •Virtually undetectable by human senses •Miscible in oil •Requires synthetic lubricant oils	• R-134a • R-152a • R-23

Molecular Structure



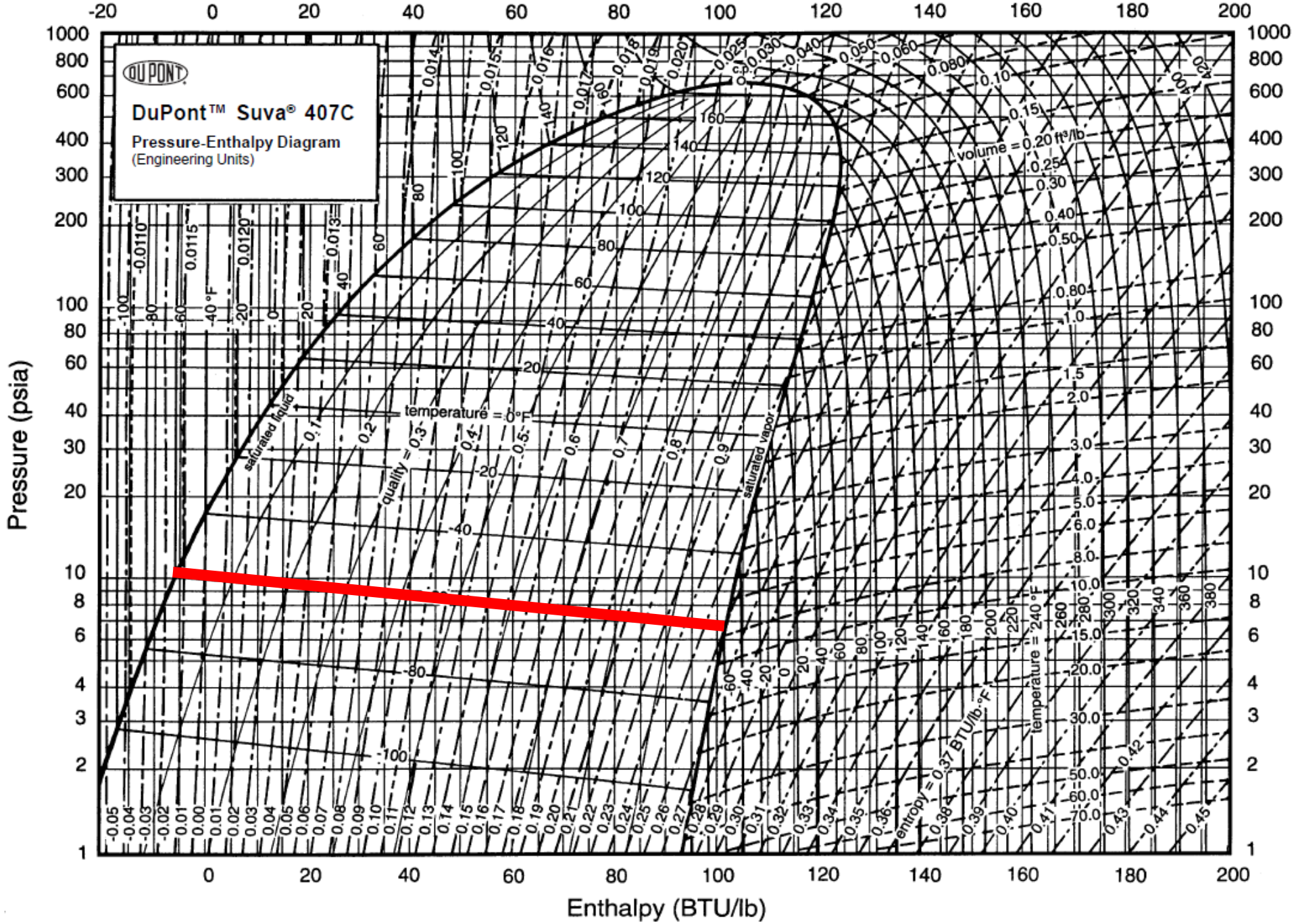
HCFC-134a

Pros/Cons - Azeotropes

Pros	Cons	Refrigerants
•Most azeotropes have either no ODP, or very slight ODP •The components of the azeotropes will not separate under normal operating conditions	•Azeotropes tend to have high GWP •Azeotropes cannot be recycled because of the blend of refrigerants that make it up	• R-500 • R-502 • R-507

Pros/Cons - Zeotropes

Pros	Cons	Refrigerants
•Many zeotropic mixtures have no ODP, or an ODP similar to that of HCFCs. •Zeotropic mixtures can improve on the thermodynamic qualities of its constituents	•Zeotropic mixtures tend to have high GWP. •Zeotropes do not maintain a constant temperature-pressure while changing states •Zeotropes cannot be recycled because of the blend of refrigerants that make it up	• R-404a • R-410a • R-407a


DuPont™ Suva® 407C
Pressure-Enthalpy Diagram
(Engineering Units)
Pressure (psia)
Enthalpy (BTU/lb)
saturated liquid
saturated vapor
quality = 0.3
temperature = 0°F
temperature = 240°F
volume = 0.20 ft³/lb
entropy = 0.37 BTU/lb-°F

Pros/Cons - Hydrocarbons

Pros	Cons	Refrigerants
•Non-toxic •No ODP •Highly efficient •Can replace many other refrigerants without requiring the oil or components being changed •Low GWP	•Extreme flammability risks	• R-290 • R-600 • R-600a

Pros/Cons - Ammonia

Pros	Cons	Refrigerants
•An ODP of zero •A GWP of less than 1 •Cheap, and easy to synthesis •Very good thermodynamic properties •Easily detectable	•Extremely toxic •Heavily regulated •Volatile •Flammable	• R-717

Future of Refrigerants?

- Packaged, air-condensing units using natural refrigerants
- Azanefreezer

Questions?