R-22 Breakout

- HCFC Phaseout
  - Keilly Witman, US EPA
- HCFC Replacement Refrigerants
  - Nick Strickland, DuPont
- Retrofit Procedures
  - Dave Demma, Sporlan
- Retailer Experiences
  - Richard Royal, Wal-Mart

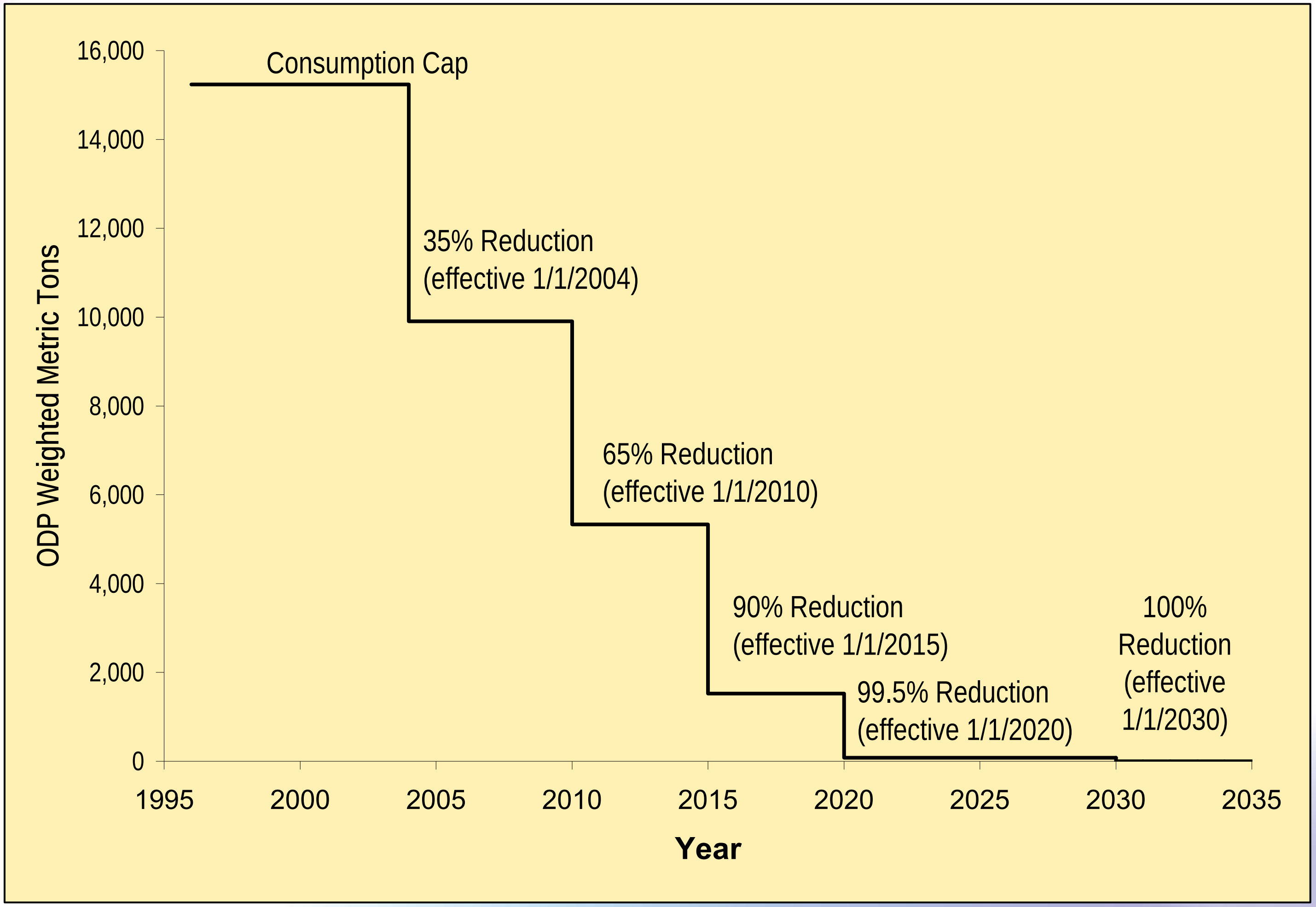
HCFC Phaseout

- Montreal Protocol
- HCFC Phaseout Schedule & Milestones
- Servicing Existing Equipment after 2010
- Options during the Transition Period
- GreenChill Retrofit Guidelines

Montreal Protocol

- Treaty to reduce production of Ozone Depleting Substances such as CFCs & HCFCs
  - HCFC Phaseout Milestone 2010
- Goals are to restore ozone layer, prevent harmful effects of ultraviolet radiation overexposure
- Outstanding environmental and health benefits
  - 6.3 million U.S. skin cancer deaths prevented by 2165

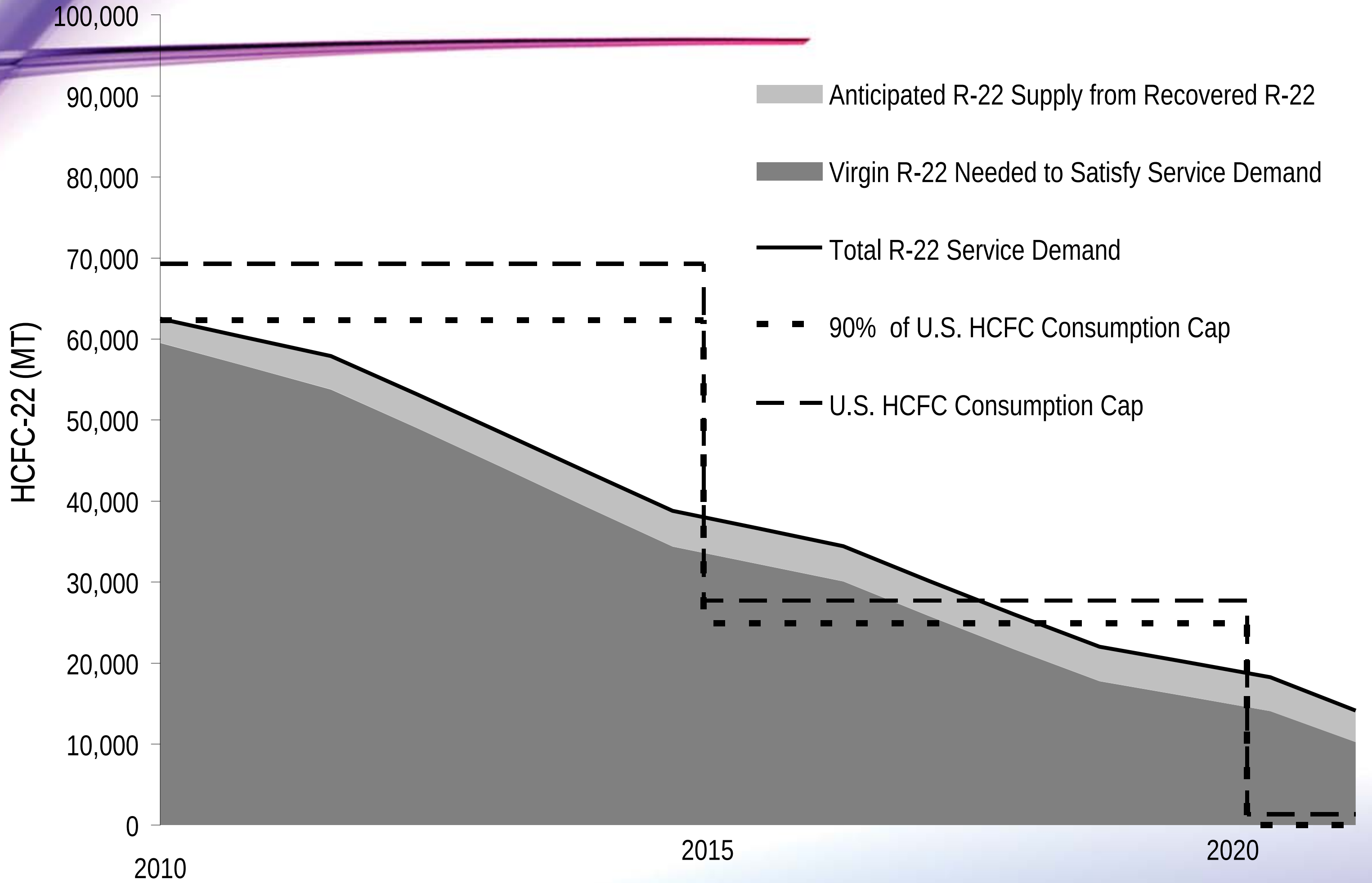
HCFC Phaseout Schedule



Milestones for HCFC Phaseout

January 1, 2010	Ban on production and import of HCFC-22 except for on-going servicing needs in equipment manufactured before January 1, 2010.
January 1, 2015	Ban on sale and use of all HCFCs except (1) for use in chemical reactions where the HCFCs are completely used up in the process, (2) reclaimed and recycled HCFCs, or (3) for on-going servicing needs in refrigeration equipment manufactured before January 1, 2010.
January 1, 2020	Ban on remaining production and import of HCFC-22.
January 1, 2030	Ban on remaining production and import of all other HCFCs.

HCFC-22 Supply and Demand



Source: EPA's Vintaging Model (VM IO file_2007_11-12-07)

Estimated R-22 Supply and Demand

Equipment Type	2010*	2015*	2020*
Total AC	41,700	25,900	11,300
Total Refrigeration	20,800	12,800	7,000
Estimated Demand of R-22	62,500	38,800	18,200
Estimated Supply (90% of cap for R-22)	62,345	24,938	0

*Metric tons of R-22

Servicing Existing HCFC-22 Equipment after 2010

- In 2015, HCFC-22 needs will exceed the 2015 cap by more than 10,000 metric tons
- Recovery and reuse needed to provide room under the cap and meet demand for all HCFCs
- What can you do?
  - Improve service practices (recover, recycle, reclaim)
  - Fix leaks
  - Retrofit/Replace where economical

Servicing Existing HCFC-22 Equipment after 2010

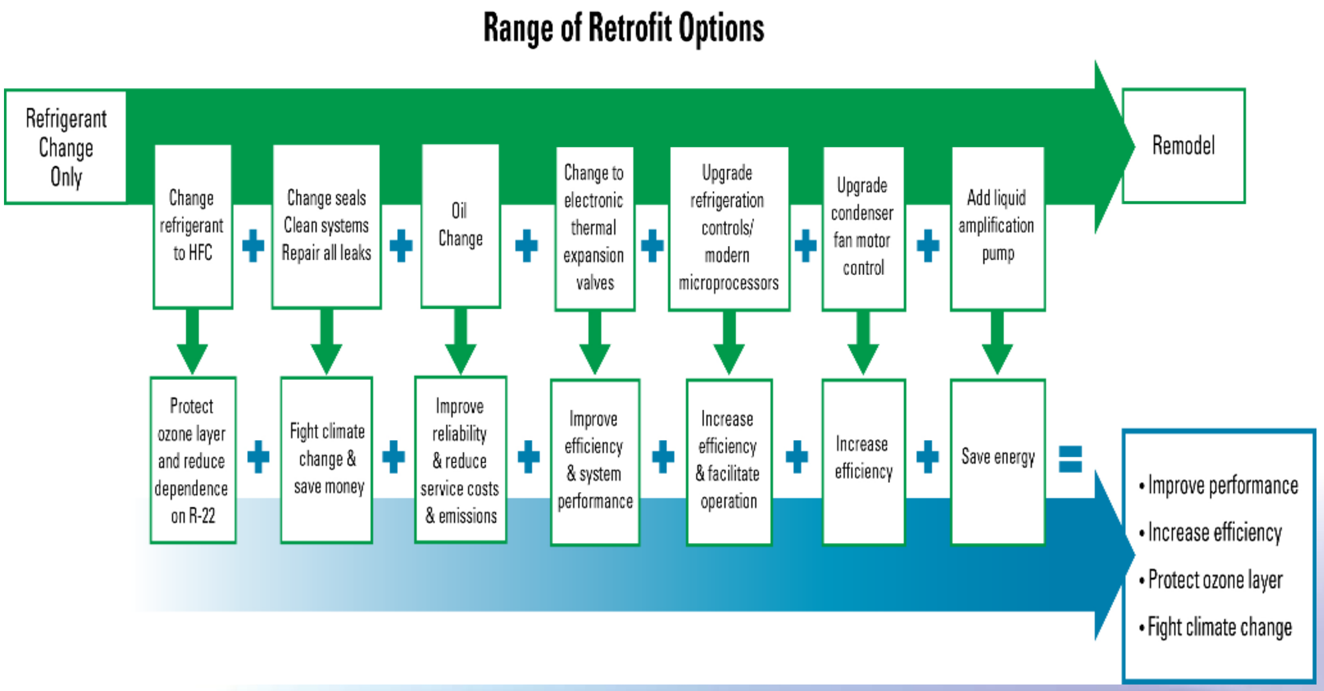
- You will not have to stop using HCFC-22
- You will not have to replace existing equipment
- Existing equipment using HCFC-22 can be serviced as usual
- After 2010, supplies of HCFC-22 will be more limited
- After 2020, only stockpiled or reclaimed supplies will be available to service equipment

During the Transition Period

- Businesses have three options:
    - Convert existing system to alternative refrigerant
    - Buy a new system that uses an alternative refrigerant
    - Continue to operate existing system
- Establish a plan to replace/repair leaking equipment
- Recover and reuse refrigerant from equipment that is discarded
- Begin to transition to alternative refrigerants
    - Many businesses have started to switch
    - Consider amount of time needed to convert

GreenChill's Retrofit Best Practice Guidelines

- Retrofits = most widespread strategy to prepare for HCFC-22 phaseout in existing stores
- Opportunity to tighten up the system!



GreenChill's Retrofit Best Practice Guidelines

- Mission & Purpose/ Scope of the Guideline
- The HCFC Situation– Why Retrofit?
  - Ozone Layer Protection and the Montreal Protocol
  - Montreal Protocol Implementation in the United States
  - HCFC-22 Supply and Demand

GreenChill's Retrofit Guidelines - Contents

- HFC Refrigerant Retrofits
  - HFC Retrofit Options
    - HFC Refrigerant only Retrofit
    - Retrofitting with New Mechanicals and HFC Refrigerant
  - Leak Tightness Improvements during Retrofits
  - Factors to consider when assessing retrofit options
  - Value/Cost Calculation
  - Lab Tests on Retrofit Refrigerants vs. HCFC-22

GreenChill's Retrofit Guidelines - Contents

- Best Practices for Transitioning to HFC Substitute Chemicals
- Conversion Guidelines for HFC Substitute Chemicals
- Best Practice Checklist for Conversion to HFC Substitute Chemicals

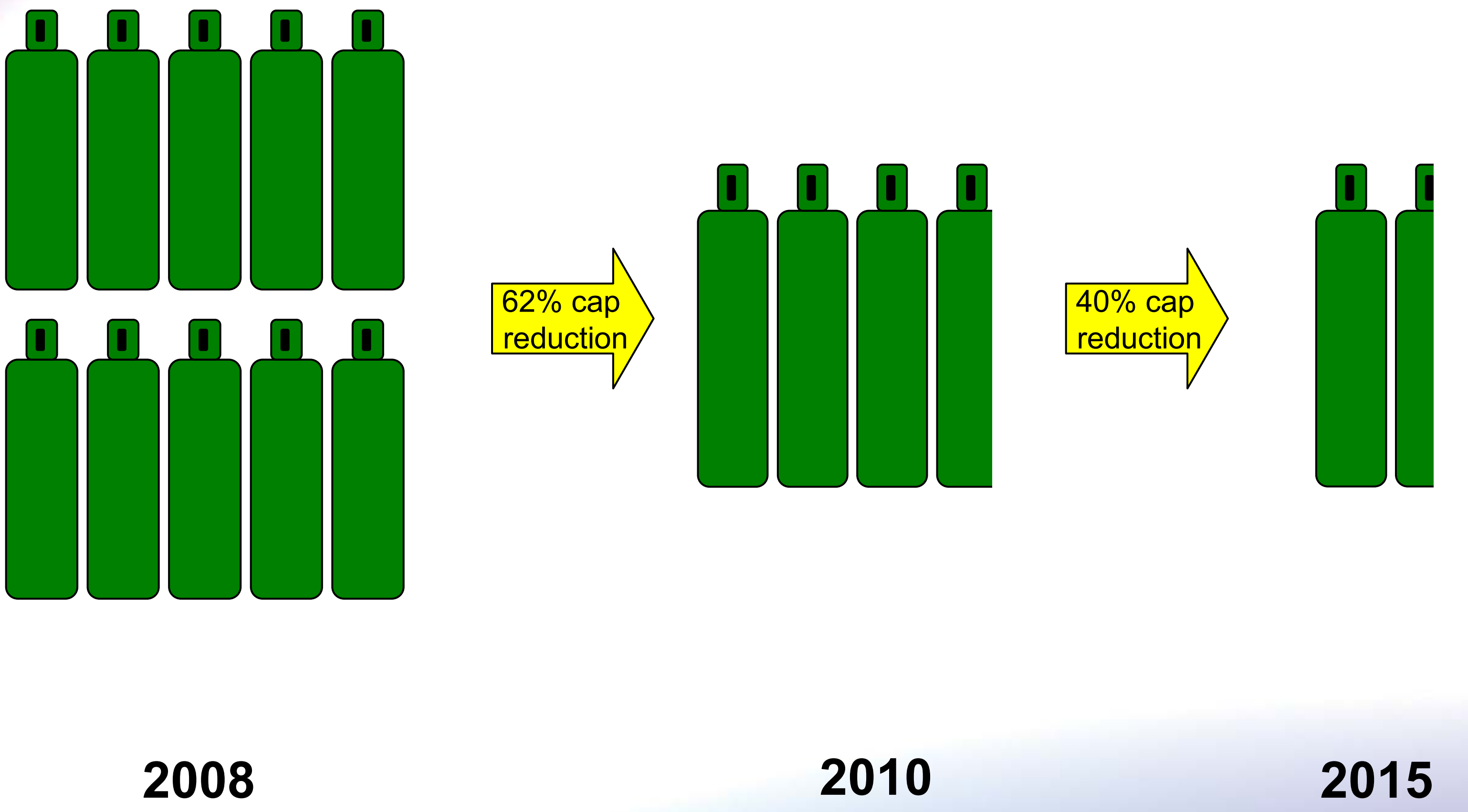
GreenChill Retrofit Guidelines - Contents

- Best Practices - HCFC-22 End of Life
  - End of Life Options for Refrigerants
  - Best Practices – Recovery, Reclamation
  - Safety Information
- Case Studies for R-422D, R407A, and 427A Retrofits
- Conversion Checklists for Specific HFC Substitute Chemicals

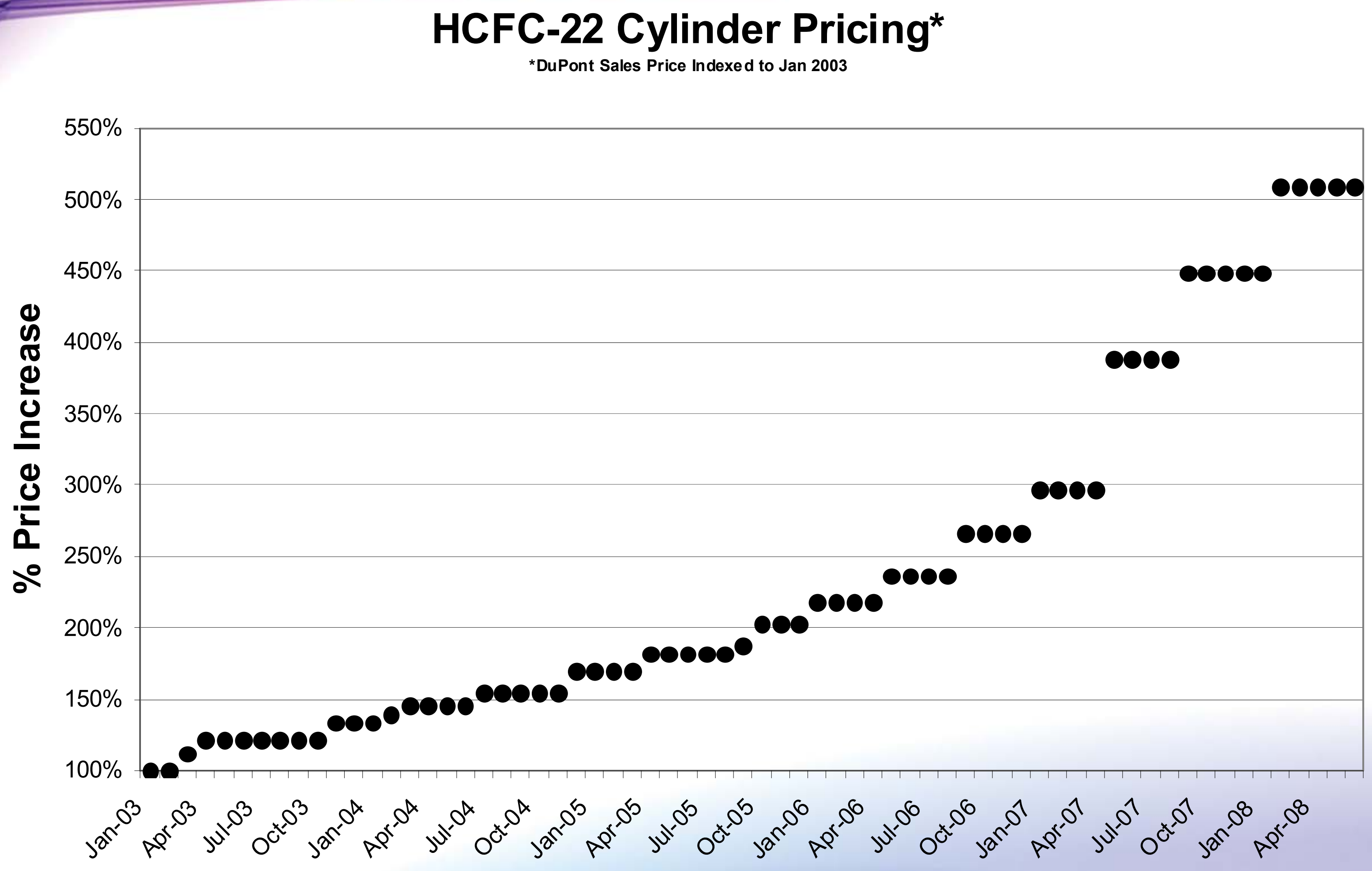
HCFC Replacement Refrigerants

- The Business Case
  - HCFC-22 is going away
  - HCFC-22 price volatility likely
  - Plan for a smooth and orderly transition
  - Concentrate on the lowest cost solution
- Refrigerant retrofits deliver value…
  - By extending the life of existing corporate assets
  - R22 is a valuable corporate asset
  - Use R22 to servicing other stores
  - Avoid heavy machine room investments
  - Free up cash for the highest ROI business investments

HCFC Replacement Refrigerants



HCFC-22 Producer Price



HCFC-22 Replacement Refrigerants Availability

- Future product availability is a function of
  - Product Acceptance
  - Producer commitment to manufacturing and selling
  - Distribution network to service retail locations

HCFC Replacement Refrigerants

Potential Alternatives	UoM	HCFC-22		R-404A		R-407C		R-422A		R-422D	
Condenser Temp	°F	80	105	80	105	80	105	80	105	80	105
Relative Med Temp Capacity (20 °F)	BTUH	1	1	1.17	1.11	1.01	0.96	1.13	1.08	1.01	0.96
65 F return gas; Sub-cooled liquid 10 °F below average condenser temperature											
Relative Low Temp Capacity (-25 °F)	BTUH	1	1	1.25	1.17	0.98	0.91	1.24	1.19	1.06	0.97
65 F return gas; Sub-cooled liquid 10 °F below average condenser temperature for 80 °F condenser conditions; Sub-cooled liquid 15 °F below average condenser temperature for 105 °F condenser conditions											
Keep TXV		Yes		No		Yes		No		Evaluation	
Keep Line Sets		Yes		Evaluation		Yes		Evaluation		Evaluation	
Relative Med Temp EER (20 °F)	BTUH/W	1	1	1	0.97	0.97	0.96	0.92	0.94	0.99	1
65 F return gas; Sub-cooled liquid 10 °F below average condenser temperature											
Relative Low Temp EER (-25 °F)	BTUH/W	1	1	1.03	1.03	0.98	0.93	1.06	1.07	1.04	1.04
65 F return gas; Sub-cooled liquid 10 °F below average condenser temperature for 80 °F condenser conditions; Sub-cooled liquid 15 °F below average condenser temperature for 105 °F condenser conditions											
Copeland Compressor Retrofit Approval		Yes		Yes		Yes		Yes		Yes	
UL Listed		Yes		Yes		Yes		Yes		Yes	
GWP	SAR	1500		3260		1530		2532		2232	
Use Mineral Oil		Yes		No		No		Yes		Yes	
Med Temp Discharge Temp	°F	186	225	149	177	170	204	144	169	148	172
Low Temp Discharge Temp	°F	230*	230*	201	225	225	230*	192	214	195	218
* Liquid Injection required to maintain 230 °F discharge temperature											

Retrofit Procedures

Things To Consider

1. Refrigerant & Oil
2. Compressor Capacity
3. Expansion Valve Sizing
4. Distributor Nozzle Sizing
5. EPR Valve Sizing
6. Pipe Sizing/Pressure Drop
7. Control Set-Points
8. Seal/Gasket Replacement

Retrofit Procedures

Retrofit Procedures

THE REAL CHOICE

Weighing The Extra Expense Of Changing Components and/or Oil

VS.

System Efficiency and Power Consumption After The Conversion

Retrofit Procedures

Refrigerant	Oil	Comments
R-417A	Mineral Oil/AlkylBenzene	May require adding 5% - 10% POE to assist with oil return
R-422A	Mineral Oil/AlkylBenzene	
R-422B	Mineral Oil/AlkylBenzene	
R-422D	Mineral Oil/AlkylBenzene	
R-434A	Mineral Oil/AlkylBenzene	
R-427A	Polyol Ester (POE)	Can tolerate up to 15% MO/AB
R-404A	Polyol Ester (POE)	Less than 5% MO
R-407C	Polyol Ester (POE)	Less than 5% MO
R-507	Polyol Ester (POE)	Less than 5% MO

Retrofit Procedures

Theoretical Compressor Capacities

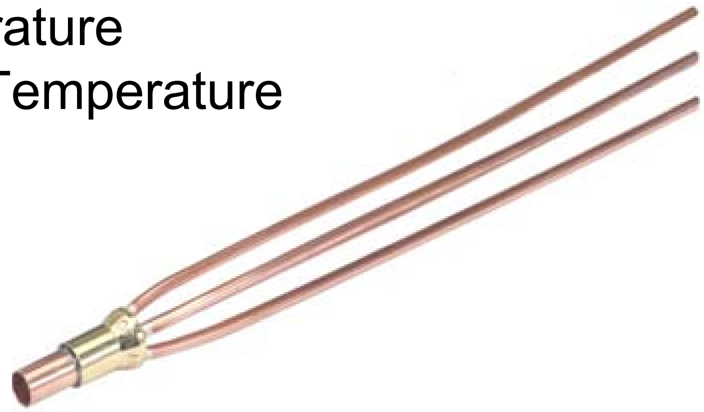
As Compared to R-22

	R-22	R-417A	R-422A	R-422D	R-404A	R-507
105ºF Condensing Temperature +20ºF Evap Temperature 50º Liquid Temperature	100%	82.6%	97%	85%	108%	108%
105ºF Condensing Temperature -25ºF Evap Temperature 50º Liquid Temperature	100%	86%	106%	90%	117%	117%

Retrofit Procedures

Distributor Capacity Based On:

1. Thermodynamic Properties of the Refrigerant
2. Feeder Tube Diameter, Nozzle Diameter
3. System Conditions
   - Evaporator Temperature
   - Liquid Refrigerant Temperature



Retrofit Procedures

R-22 Distributor Feeder Tubes & Nozzle Selections.
Selected Before TEV (ΔP will affect TEV Capacity).

REFRIGERANT DISTRIBUTOR SELECTION DATA

Refrigerant R- 22 **Number of Circuits: 4**

Evaporator Temperature (°F): -20 **Dist Tube Length (in): 30**

Liquid Temperature (°F): 50 **Evaporator Capacity (Btu/hr): 16000**

Tube OD (in)	Tube DP (psi)	Percent Loading	Nozzle Orifice Number	Nozzle DP (psi)	Percent Loading	Total DP (psi)
3/16	13	124	1	27	109	40

Retrofit Procedures

Distributor Tube/Nozzle Capacities for Alternative Refrigerants using existing R-22 Selections

18,000 Btu Evaporator -20ºF Evap Temperature 50º Liquid Temperature	R-22	R-407C	R-422A	R-422D	R-404A	R-507
Feeder Tube ODF	3/16”	3/16”	3/16”	3/16”	3/16”	3/16”
Feeder Tube ΔP	13 psi	17 psi	23 psi	22 psi	19 psi	20 psi
Feeder Tube % Loading	124%	152%	200%	197%	170%	171%
Nozzle Size	#1	#1	#1	#1	#1	#1
Nozzle ΔP	27 psi	34 psi	42 psi	37 psi	38 psi	39 psi
Nozzle % Loading	109%	134%	168%	152%	151%	154%
Total Distributor ΔP	40 psi	51 psi	65 psi	59 psi	57 psi	59 psi
Replace Nozzle	-------	No	Yes #2	Yes #2	Yes #2	Yes #2

Retrofit Procedures

TEV Capacity Based On:

1. Thermodynamic Properties of the Refrigerant
2. TEV Pin, Port, and Stroke Dimensions
3. System Conditions
    - Evaporator Temperature
    - Liquid Refrigerant Temperature
    - Pressure Drop Across TEV Port

Retrofit Procedures

R-22 TEV Selection For Summer/Winter Conditions (ΔP from Distributor Selection Used).

THERMOSTATIC EXPANSION VALVE SELECTION DATA

Refrigerant R- 22	**Liquid Temperature (°F): 50**
Evaporator Temperature (°F): -20	**Dist & High Side Loss (psi): 41**
Condenser Temperature (°F): 115 (70)	**Evaporator Capacity (Btu/hr): 16000**
Subcooling at TEV inlet (°F): 64 (18)	**DP Across TEV (psi): 187 (66)**

Suggested Thermostatic Charge: VZ or VZP40

Valve Description	Percentage of Rated Capacity
EGVE-2	59 (99)

Retrofit Procedures

TEV Capacities For Alternative Refrigerants Using R-22 Selections

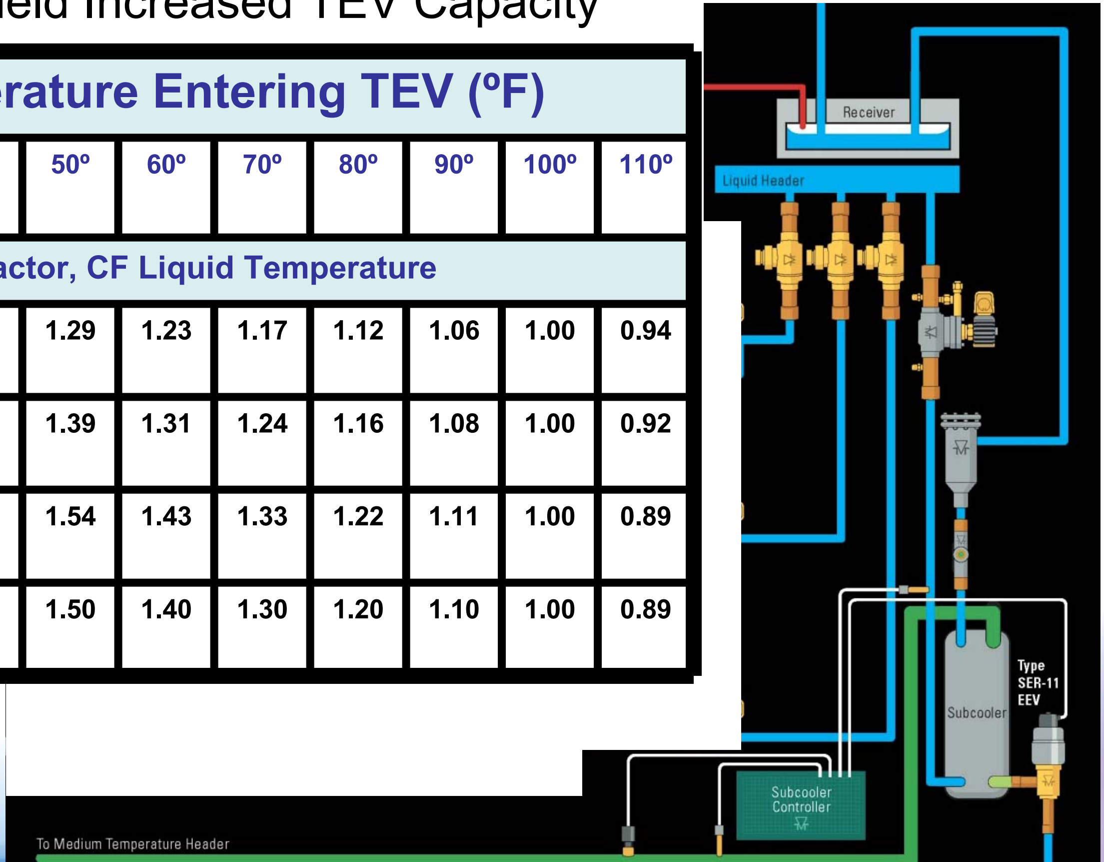
18,000 Btu Evaporator - 20ºF Evap Temperature 50º Liquid Temperature	R-22	R-407A	R-422A	R-422D	R-404A	R-507
TEV Selection (using R-22 Distributor Tubes/Nozzle)	EGVE 2	EGVE 2	EGSE 1-1/2	EGVE 2	EGSE 1-1/2	EGPE 1-1/2
Thermostatic Element Change Required ?	______	No	Yes SZ/SZP	No	Yes	Yes SZ/SZP
Nominal TEV Capacity After Element Replacement	______	2 Ton	1-1/2 Ton	2 Ton	1-1/2 Ton	1-1/2 Ton
% Rated Capacity at 115ºF Condensing	59%	58%	74%	84%	65%	66%
% Rated Capacity at 70ºF Condensing	99%	97%	131%	149%	113%	115%
Valve Replacement Required?	______	No	Yes EGSE-2	Yes EGVE-3	Possible EGSE-2	Possible EGSE-2

Retrofit Procedures

An Alternative To Replacing TEVs

Lower Liquid Temperatures Yield Increased TEV Capacity

Refrigerant	Liquid Temperature Entering TEV (ºF)											
	0º	10º	20º	30º	40º	50º	60º	70º	80º	90º	100º	110º
	Correction Factor, CF Liquid Temperature											
R-22	1.56	1.51	1.45	1.40	1.34	1.29	1.23	1.17	1.12	1.06	1.00	0.94
R-407A	1.75	1.68	1.61	1.53	1.46	1.39	1.31	1.24	1.16	1.08	1.00	0.92
R-404A	2.04	1.94	1.84	1.74	1.64	1.54	1.43	1.33	1.22	1.11	1.00	0.89
R-507	1.99	1.89	1.79	1.69	1.59	1.50	1.40	1.30	1.20	1.10	1.00	0.89



Retrofit Procedures

EPR Capacity Based On:

1. Evaporator Temperature
2. Suction Vapor Temperature
   - ΔP Across Valve Port (Difference between EPR Set-Point and Common Suction Pressure – *for the circuit with the lowest design temperature this should be kept to a minimum).*

Retrofit Procedures

R-22 EPR Selection:

EVAPORATOR PRESSURE REGULATOR SELECTION DATA

Refrigerant R- 22 **Liquid Temperature (°F): 50**

Common Suction Temp (°F): -21.5 **Suction Vapor Temp (°F): 50**

EPR Valve Setting (°F): -20 **Evaporator Capacity (Btu/hr): 18000**

Pressure Drop Available Across Valve (psi): 0.86

Valve Description	Valve Type	Req'd Pressure Drop (psi)	Percentage of Rated Capacity
(S)ORIT-12 0/100	Piloted Externally	0.82 psi	98%

Retrofit Procedures

An Undersized EPR Requires A Lower Suction Pressure To Maintain Fixture Design Temperature

18,000 Btu Evaporator - 20ºF Evap Temperature -21.5ºF Common Suction 50ºF Liquid Temperature 50ºF Return Vapor Temperature	R-22	R-407A	R-422A	R-422D	R-404A	R-507
EPR Valve	(S)ORIT-12	(S)ORIT-12	(S)ORIT-12	(S)ORIT-12	(S)ORIT-12	(S)ORIT-12
Required Pressure Drop	.82 psi	1.0 psi	1.3 psi	1.4 psi	1.0 psi	1.0 psi
Available Pressure Drop	.86 psi	,82 psi	1.0 psi	.83 psi	1.0 psi	1.1 psi
% of Rated Capacity	98%	108%	113%	130%	100%	100%
Use Existing Valve Lower Suction Pressure	---------	Yes	Yes	Yes	---------	---------
Replace Valve	---------	Yes	Yes	Yes	---------	---------
New Selection	---------	(S)ORIT-15	(S)ORIT-15	(S)ORIT-15	---------	---------

Retrofit Procedures

Setting Changes:

18,000 Btu Evaporator -20ºF Evap Temperature 50º Liquid Temperature	R-22	R-407A	R-422A	R-422D	R-404A	R-507
EPR Setting: -20ºF	10.2 psi	8.5 psi	14.5 psi	8.1 psi	16 psi	17.6 psi
Subcooler EPR Setting: 40ºF	68.5 psi	69.4 psi	83.5 psi	66.4 psi	85.4 psi	89.2 psi
Condenser Holdback Valve: Pressure Equivalent to 70ºF	121.4 psi	148.8 psi	152 psi	132.5 psi	149.3 psi	153 psi
Receiver Bypass Valve: 20 psi Less Than Condenser Holdback Valve	101.4 psi	128.8 psi	132 psi	112.5 psi	129.3 psi	133 psi
Common Suction Header Target Pressure (-21.5ºF)	9.4 psi	7.6 psi	13.6 psi	7.3 psi	16.5 psi	15 psi
Condenser Fan Cycling Pressure Controls, Alarm Set-Points,	Check With Equipment Manufacturer For Recommendations					
Safety Relief Valves	Check With Equipment Manufacturer For Recommendations					

Retrofit Procedures
Seals and Gaskets

Refrigerants and Lubricants:

How Do They Affect Elastomers?

Test Results Show:

A certain amount of swell, and loss of physical properties when exposed to refrigerants/oil.

Retrofit Procedures
Seals and Gaskets

Neoprene W…when exposed to:

<u>New Installation</u>

R-22/Mineral Oil results in a 4.1% swell.
R-404A/POE Oil results in a 3% swell.

<u>Refrigerant Conversion</u>

R-22/Mineral Oil retrofit to R-404A/POE Oil:

Elastomer Swell is reduced to 2.6%

Retrofit Procedures
Seals and Gaskets

Components which require may have elastomer gaskets/seals…if so, replacement is required.

- **Solenoid valves**
- **3-way reversing valves**
- **Schraeder valve cores and caps.**
- **Evaporator Pressure Regulators (EPRs).**
- **Some older style ball valves may need replacement.**

Retrofit Procedures

Contaminants:

- A thorough system evacuation is essential.
- Replace oil filter.
- Replace suction line filters.
- Replace liquid line filter-driers.

- Oil breakdown deposited on the interior walls of system piping will be brought back into circulation if POE oil is used. Close monitoring of the oil will reveal whether additional action is required.

Retailer Experiences

- Conversion data
- Conversion engineering process
- Capacity, Oil, Valves, others
- Refrigerant choice
- Follow up on maintenance, MO to POE
- Lifecycle cost, total cost of ownership
- Leak potential variability post conversion

Conversion Data

- 561 Stores converted
- 302 are R-404A
- 253 are R-422D
- 4 are R-422A
- 1 is R-407A
- 1 is R-427A

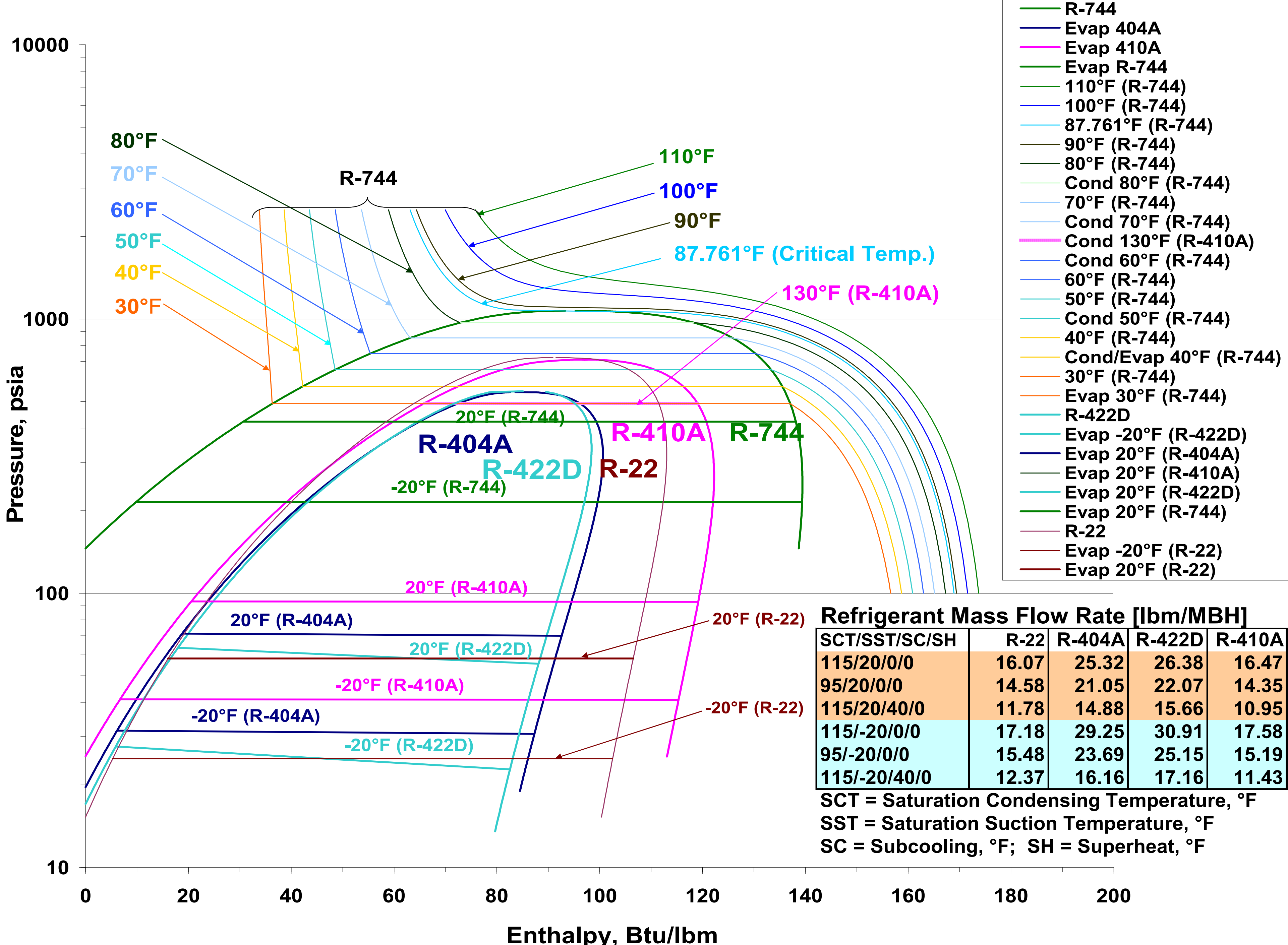
Conversion Engineering

- What is important to know and consider?
- Capacity, Line Sizing, Oil, Valves
- Refrigerant choice
- Controls set points
- Follow up on maintenance, oil changes
- Leak potential after the conversion
- Lifecycle cost, total cost of ownership

Refrigerant Choice

- High Performance
  - Thermophysical properties
  - System mass flow requirements
- System Capacity
- Control Set points
- Low Refrigerant Inventory
- Oil and Valves
- Follow up on maintenance, MO to POE
- Lifecycle cost, total cost of ownership
- Leak potential variability post conversion
- Different refrigerants…think outside the box

P-h Diagram R-404A, R-410A, R-744, and R-422D

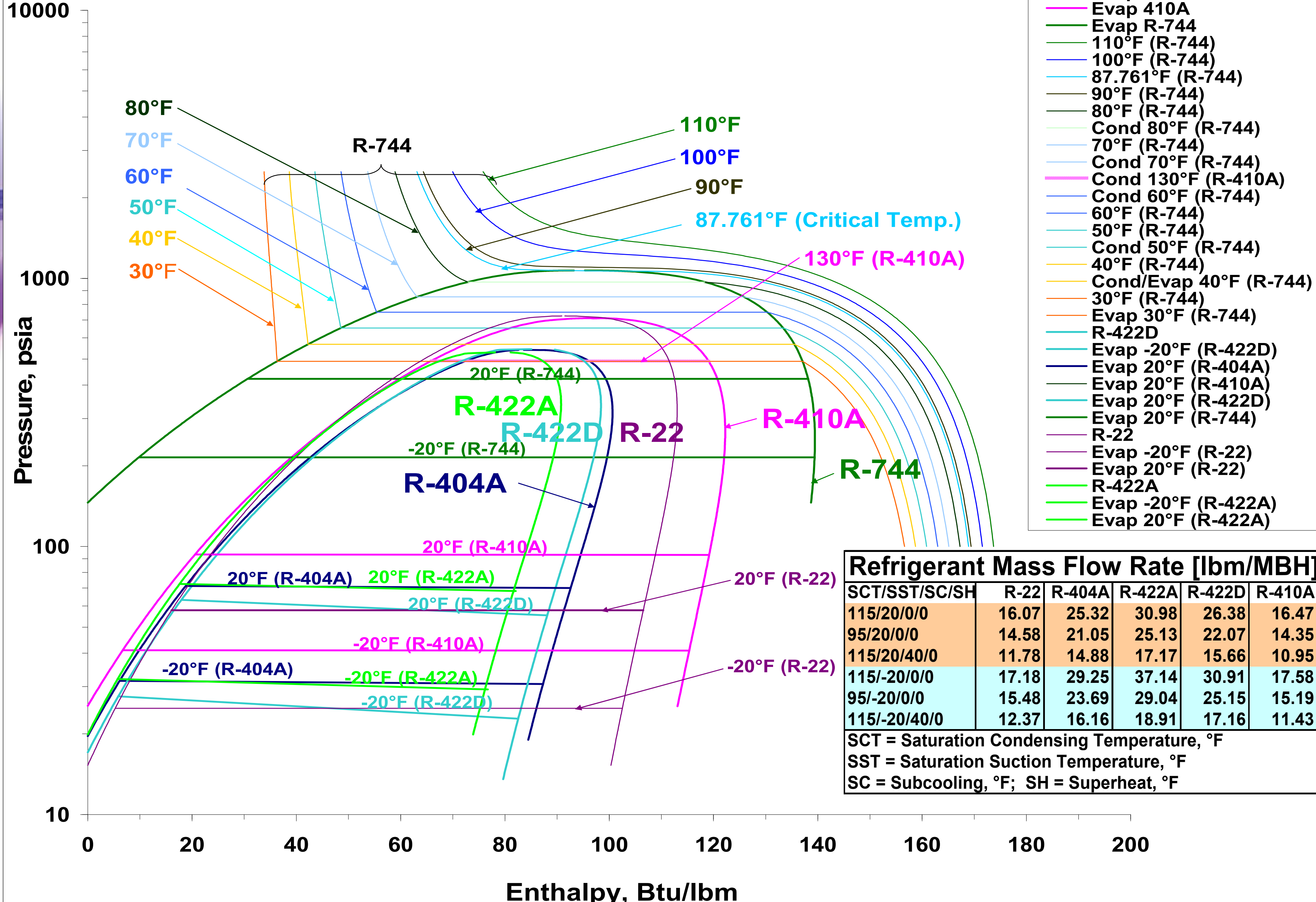


Refrigerant Mass Flow Rate [lbm/MBH]

SCT/SST/SC/SH	R-22	R-404A	R-422D	R-410A
115/20/0/0	16.07	25.32	26.38	16.47
95/20/0/0	14.58	21.05	22.07	14.35
115/20/40/0	11.78	14.88	15.66	10.95
115/-20/0/0	17.18	29.25	30.91	17.58
95/-20/0/0	15.48	23.69	25.15	15.19
115/-20/40/0	12.37	16.16	17.16	11.43

SCT = Saturation Condensing Temperature, °F
SST = Saturation Suction Temperature, °F
SC = Subcooling, °F; SH = Superheat, °F

P-h Diagram R-22, R-404A, R-422A, R-422D, R-410A, and R-744



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95/20/0/0	14.58	21.05	25.13	22.07	14.35
115/20/40/0	11.78	14.88	17.17	15.66	10.95
115/-20/0/0	17.18	29.25	37.14	30.91	17.58
95/-20/0/0	15.48	23.69	29.04	25.15	15.19
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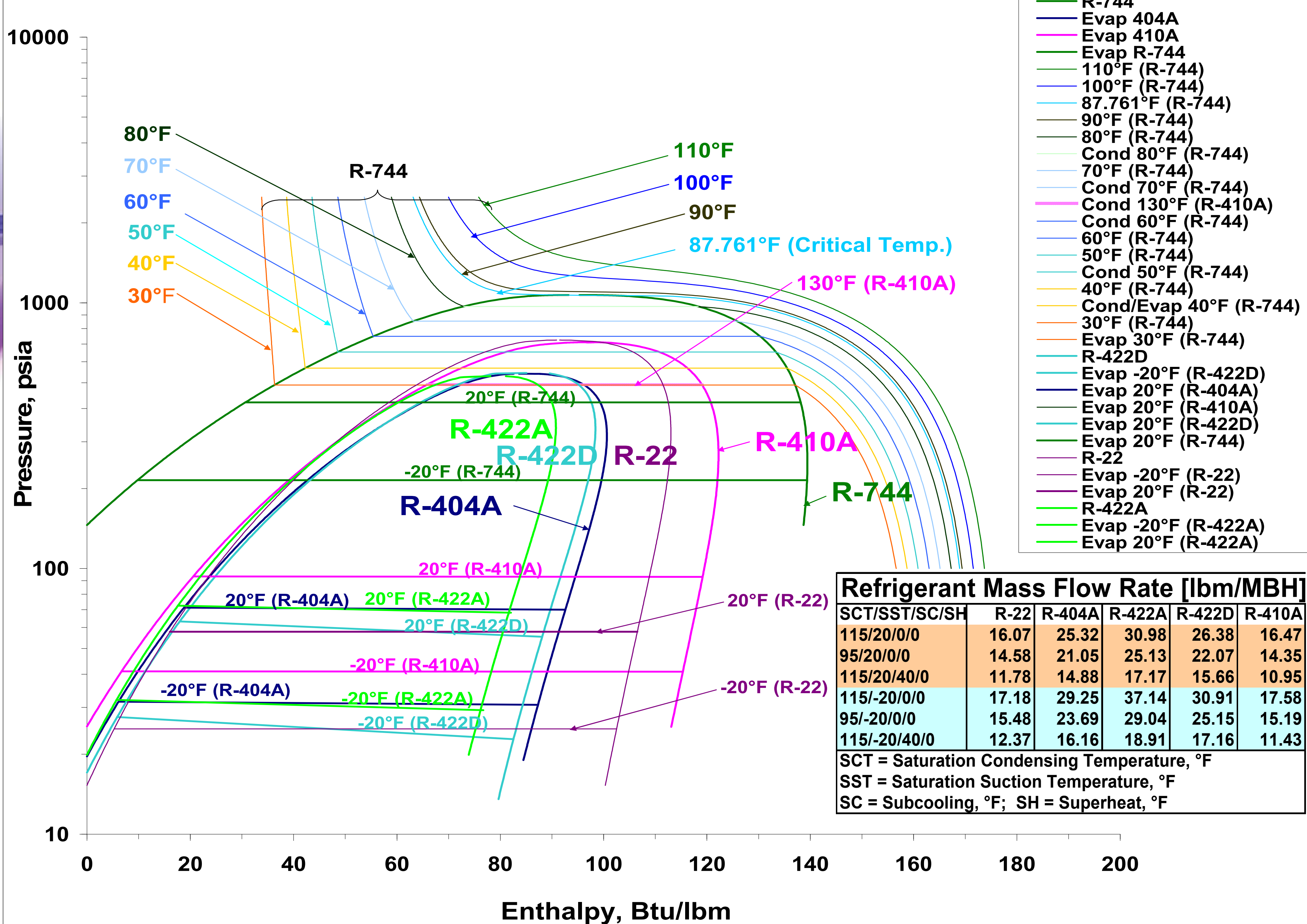

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115/20/40/0	11.78	14.88	17.17	15.66	10.95
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SCT = Saturation Condensing Temperature, °F
SST = Saturation Suction Temperature, °F
SC = Subcooling, °F; SH = Superheat, °F

Max return gas temperature

Note: Discharge-line temperature within 6 inches of the compressor outlet will be from 25°R to 75°R cooler than cylinder & piston temps depending on the compressor design and the refrigerant mass flow.

Calculation of the max return gas temperature at which the temperature at the end of isentropic compression will not exceed 300°F (max temp for good long-life characteristics).

$\eta is = Pis/Pel$; $Pel = Pis/\eta is$;

$Q = Pel - Pis = Pis/\eta is - Pis = Pis(1-\eta is)/\eta is = cp\,(T1 - T_{RG})$

$T1 - T_{RG} = 1/cp\ Pis\,(1-\eta is)/\eta is = 1/cp\,(his2 - his1)\,(1-\eta is)/\eta is$

cp = 0.205 Btu/(lbm.°R);

his2 - his1 = 238.7 - 201 = 37.7 Btu/lb

$T1 - T_{RG} = 37.7/0.205(1 - \eta is)/\eta is$

Table: Max return gas temperature for not exceeding 300°F at the end of isentropic compression

Refrigerant: R-410A; SST = -20°F; SDT = 110°F

Symbols: T1 - Temp. at the beginning of isentropic compression; TRG - Return gas temp.;

ηis - Compressor isentropic efficiency.

ηis	0.7	0.72	0.74	0.76	0.78	0.8
$T1 - T_{RG}$, °R	79	72	65	58	52	46
T_{RG}, °F	**20**	**27**	**34**	**41**	**47**	**53**

Total Cost of Ownership - TCO

- Equipment Costs
- Installed Costs
- Operational Costs (energy)
- Maintenance Costs
- Environmental Stewardship
- TCO has to be simple and cost effective

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- Richard Royal, Wal-Mart
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- **For Sec. 608: Julius Banks,**
- **banks.julius@epa.gov, 202-343-9870**

- **GreenChill Advanced Refrigeration Partnership**
- **www.epa.gov/greenchill**

- **Additional Info:**
- **http://www.epa.gov/ozone/title6/phaseout/classtwo.html**
- **http://www.epa.gov/ozone/title6/allowance.html**