



DuPont™ Suva® DuPont™ ISCEON® & DuPont™ Opteon® Refrigerants

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DuPont Fluorochemicals

April 2013



Agenda

- 1. DuPont and Refrigerants**
- 2. Refrigerant Change Management**
- 3. DuPont™ Suva®**
- 4. DuPont™ ISCEON®**
- 5. DuPont™ Opteon®**
- 6. Conclusions**

Over 80 Years of Industry Leadership

- **1930s - Introduced the Safe and Efficient Freon® Refrigerants making refrigeration available to all.**
- **1990s – Introduced the first Non-Ozone Depleting Suva® Refrigerants to Replace CFCs and HCFCs**
- **2000s – Introducing the Easy Retrofit option ISCEON® Refrigerants extending the life of CFC and HCFC designed equipment.**
- **2010s – Introducing Low GWP Opteon® Refrigerants to further reduce the environmental impact of refrigerants.**

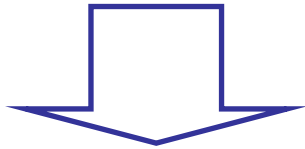
Phase-Out of Ozone Depleting Substances and HCFC Consumption in Russia

Implementation Year	% Reduction from base year (1990)	Max Consumption ODP Tonnes
2010	75%	999.23
2015	90%	399.69
2020	99.5%	19.98
2030	100%	0

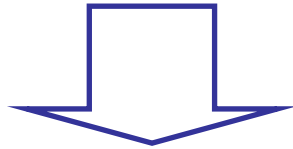
Based on R-22 annual consumption the R-22 bank within installed refrigeration and A/C equipment is estimated at 30-40 Thousand Tonnes.

HCFC-Phase-Out Options

Four Options

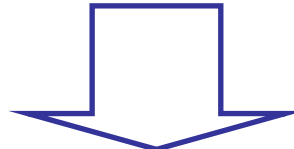


- **Maintain operation using HCFCs= Risk!**



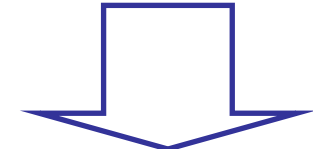
- **Replace with new equipment running on:**

- ammonia
- hydrocarbons
- CO₂
- HFC, e.g. Suva®



- **Keep running existing equipment - change of oil and further technical modifications are required:**

- HFCs of the Suva® range, e.g. Suva®404A or Suva®407C



- **Keep running existing equipment – only moderate modifications are necessary:**

- **retrofit with DuPont™ ISCEON® 9 Series Refrigerants**

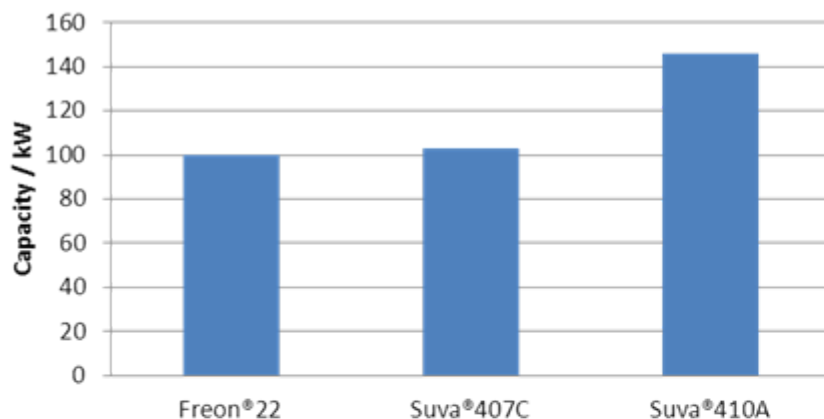


DuPont™ Suva® Refrigerants

Application	Traditional	New Equipment	Comments
DX Air Conditioning & Heat Pumps	R22	Suva® 407C Suva® 410A	Must be used with POE lubricants. Suva® 410A only suitable for new equipment
Commercial & DX Industrial Refrigeration	R22 R502	Suva® 404A Suva® 507A Suva® 407A	Suva® 404A and Suva® 507A have a relatively high GWP and energy efficiency reduces as the evaporator temperature rises. Suva® 407A has a moderate GWP with good energy efficiency at low and medium temperature applications
DX Chillers	R12 R22	Suva® 134a Suva® 407C Suva® 410A	Suva® 134a offers the best energy efficiency but where equipment footprint is important Suva® R410A offers a good solution
Flooded Chillers & Low Pressure Chillers	R12 R123	Suva® 134a	Suva® 134a is currently the only option commercially available

Refrigerant Comparison – DX Air Conditioning

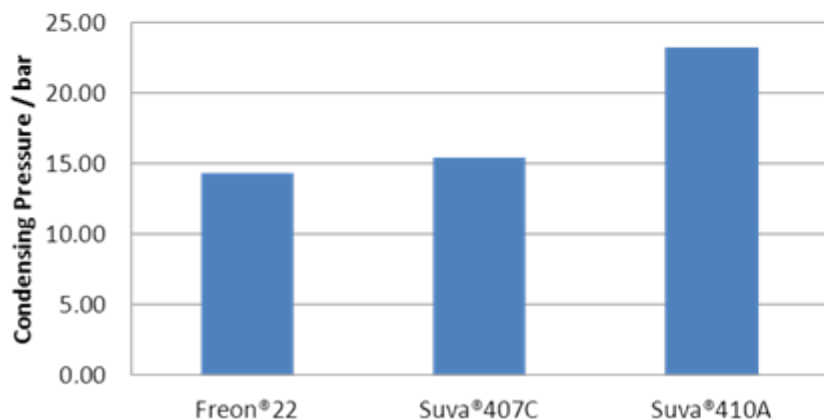
Cooling Capacity Comparison



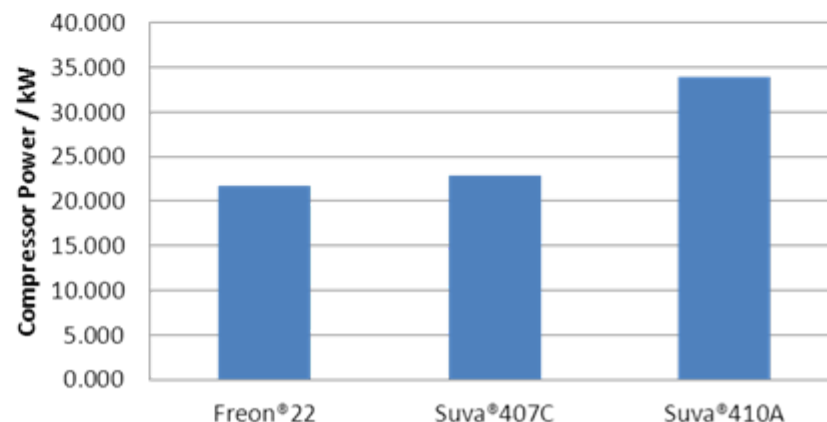
Suva®407C has very similar properties to Freon®22.

Suva®410A has a much higher cooling capacity, higher condensing pressure and higher compressor power but extremely good heat transfer coefficient gives a higher C.O.P. than Freon®22 and Suva®407C. Only suitable for equipment designed for Suva®410A.

Condensing Pressure Comparison



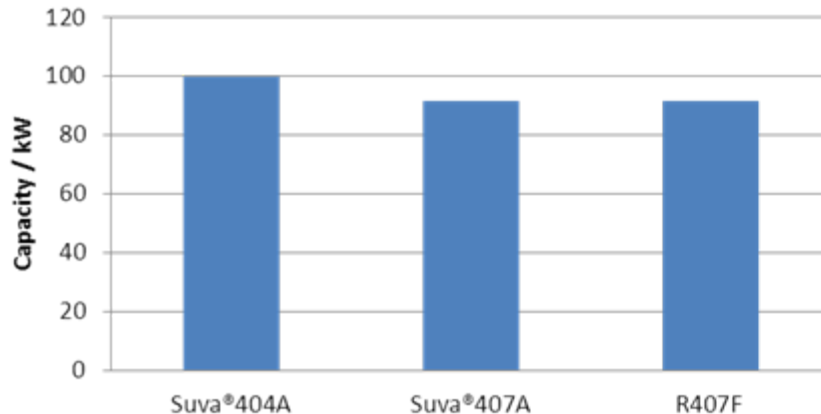
Compressor Power Comparison



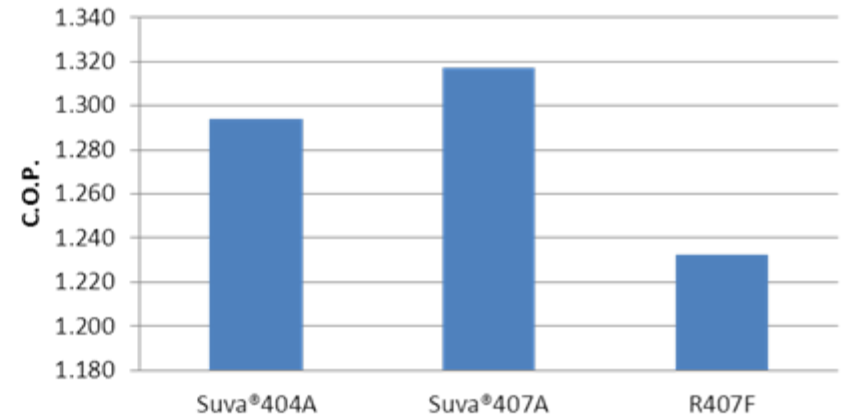
Evaporating Temperature = 5°C, Condensing Temperature = 40°C,
Total Subcool = 7K, Total Superheat = 15K

Refrigerant Comparison – Low Temperature (-35°C Evap Temp)

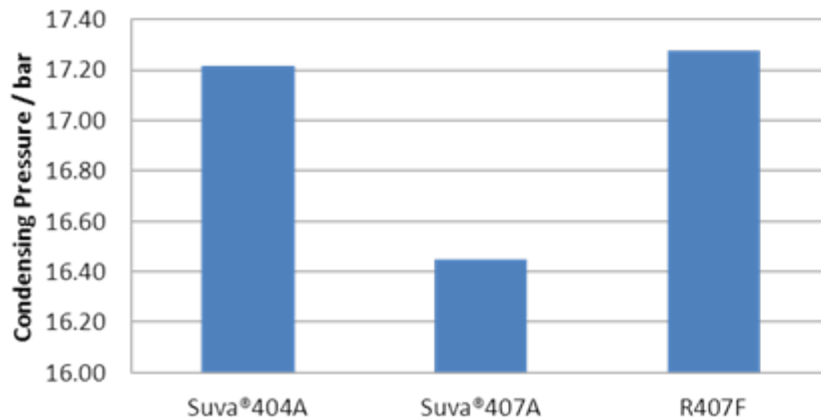
Cooling Capacity Comparison



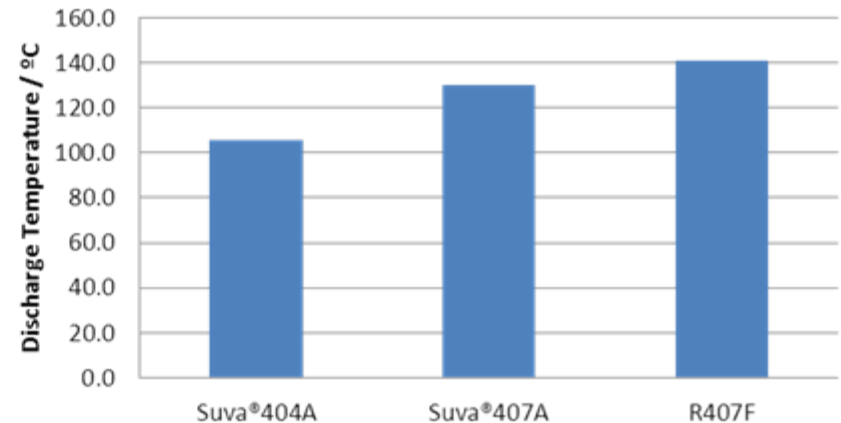
C.O.P. Comparison



Condensing Pressure Comparison



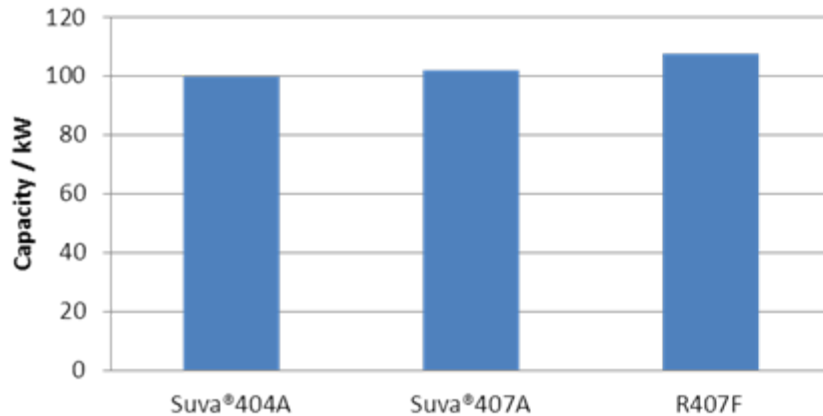
Compressor Discharge Temperature



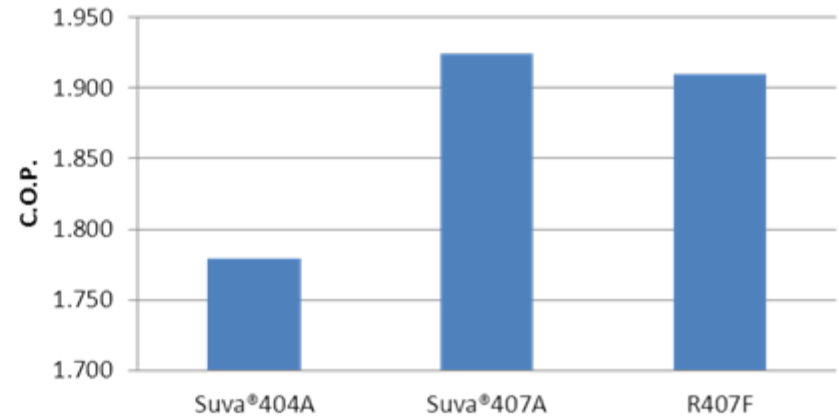
Evaporating Temperature = -35°C, Condensing Temperature = 40°C,
Total Subcool = 10K, Total Superheat = 35K, Liquid injection above 123°C

Refrigerant Comparison – Medium Temperature (-15°C Evap Temp)

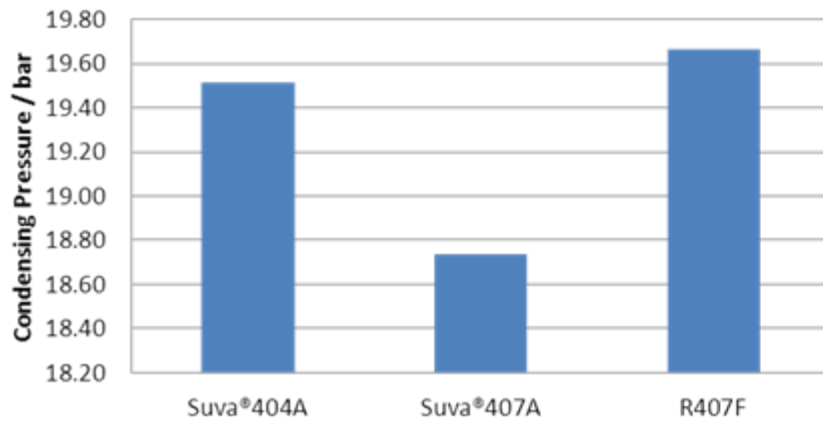
Cooling Capacity Comparison



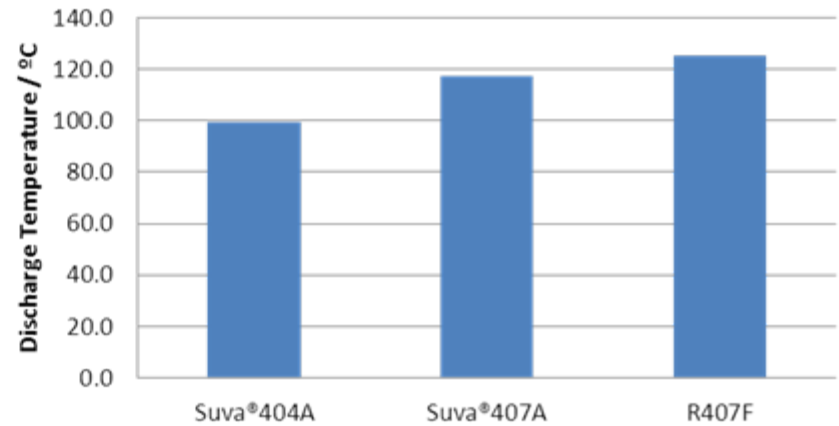
C.O.P. Comparison



Condensing Pressure Comparison



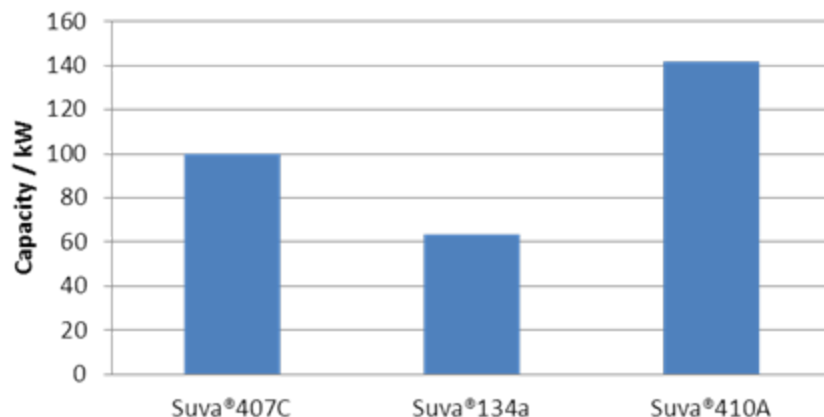
Compressor Discharge Temperature



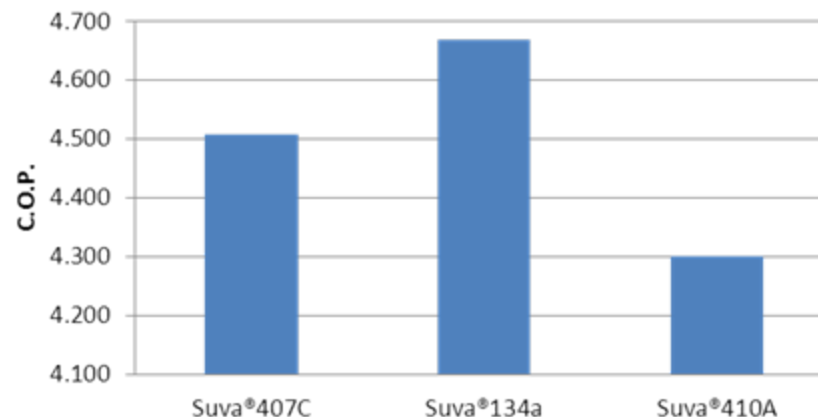
Evaporating Temperature = -15°C, Condensing Temperature = 45°C,
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Refrigerant Comparison – DX Chillers

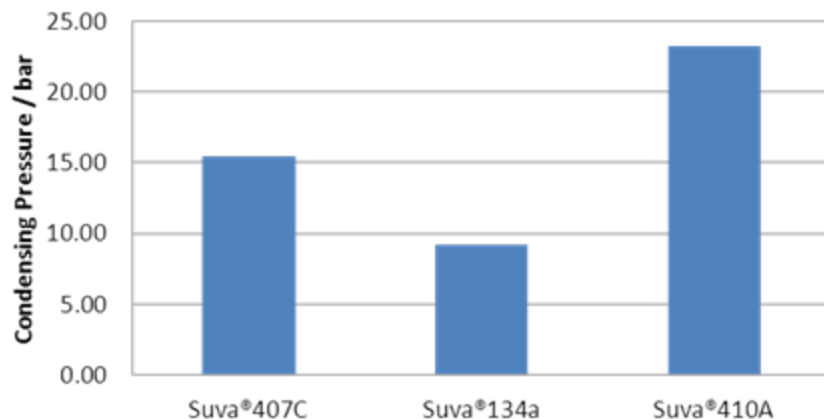
Cooling Capacity Comparison



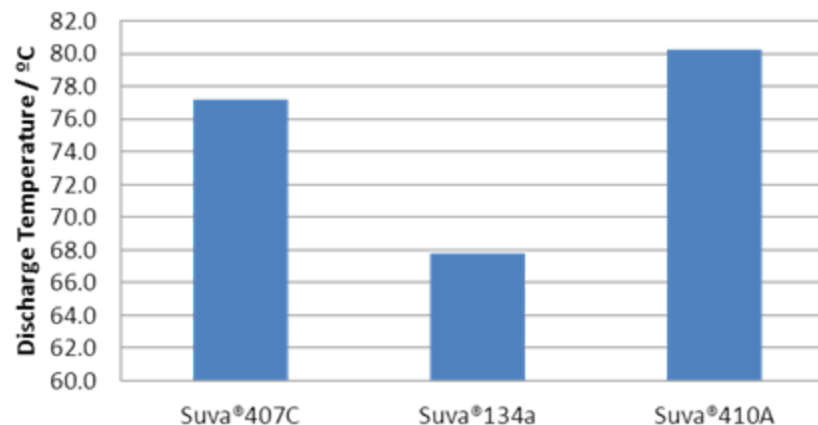
C.O.P. Comparison



Condensing Pressure Comparison



Compressor Discharge Temperature



Evaporating Temperature = 5°C, Condensing Temperature = 40°C,
Total Subcool = 7K, Total Superheat = 15K

DuPont™ ISCEON® refrigerants

The DuPont™ ISCEON® family of cost-effective, non-ozone-depleting retrofit refrigerants for CFC and HCFC enables the continued use of existing cooling units while avoiding expensive equipment replacement. Downtime due to the actual retrofitting process is minimal as in many cases the existing Alkyl Benzene or Mineral Oils can still be use.

ISCEON® refrigerants help facilitate compliance with environmental regulations, and afford an opportunity to demonstrate environmental responsibility with a more sustainable refrigerant solution.



ISCEON® Refrigerants Retrofit Procedure

1. Obtain Baseline Data on Original Refrigerant
2. Recover old refrigerant
3. Change critical elastomeric seals
4. Change filter driers
5. Evacuate
6. Charge with selected ISCEON® Alternative
7. Start-up and monitor
8. Leak Check, Label system, and optimize set-points if needed

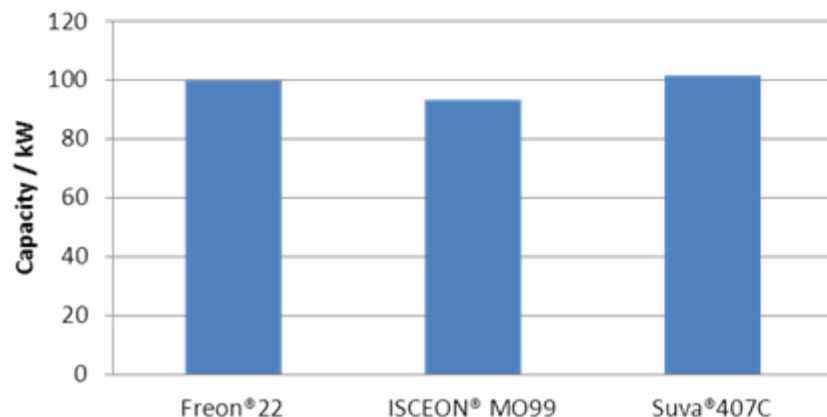
****ISCEON® Retrofit Guidelines and
ISCEON® Retrofit Video – www.isceon.com***

DuPont™ ISCEON® Refrigerants

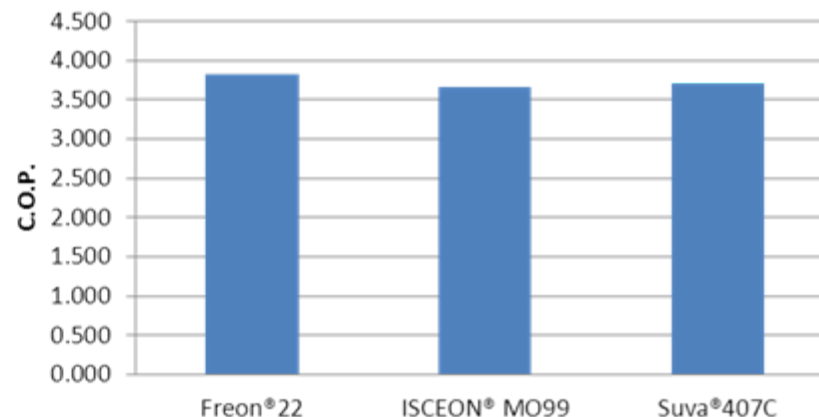
Application	Traditional	HCFC Alternative	Zero ODP Retrofit Option
DX Air Conditioning & Heat Pumps	R22	R22	ISCEON®MO99 (R438A)
Commercial Refrigeration	R12 R22 R502	R401A,R401B, R402A,R402B, R403A, R408A, R409A, R409B	ISCEON®MO49Plus (R437A) ISCEON®MO99 (R438A) ISCEON®MO79 (R422A)
DX Industrial Refrigeration	R22 R502	R402A,R402B, R403A, R408A	ISCEON®MO99 (R438A) ISCEON®MO79 (R422A)
DX Chillers	R12 R22	R401A,R401B, R409A R22	ISCEON®MO49Plus (R437A) ISCEON®MO99 (R438A)
Centrifugal Chillers	R12		ISCEON®39TC (R423A)
Low Temperature (<-40°C)	R13B1		ISCEON® MO89

Refrigerant Comparison – DX Air Conditioning

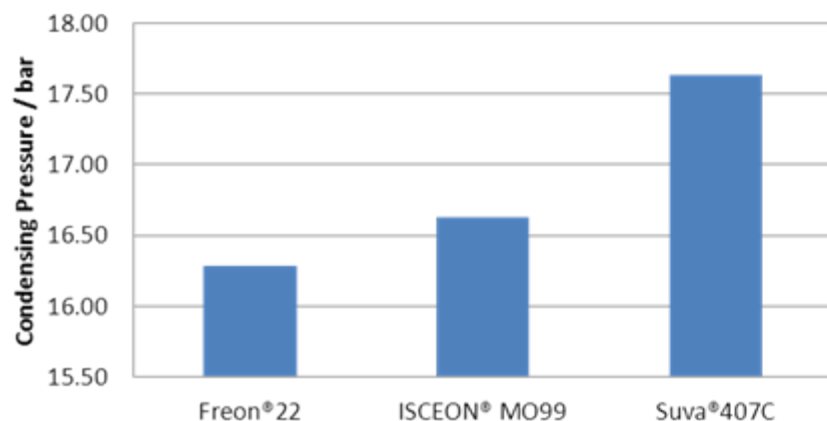
Cooling Capacity Comparison



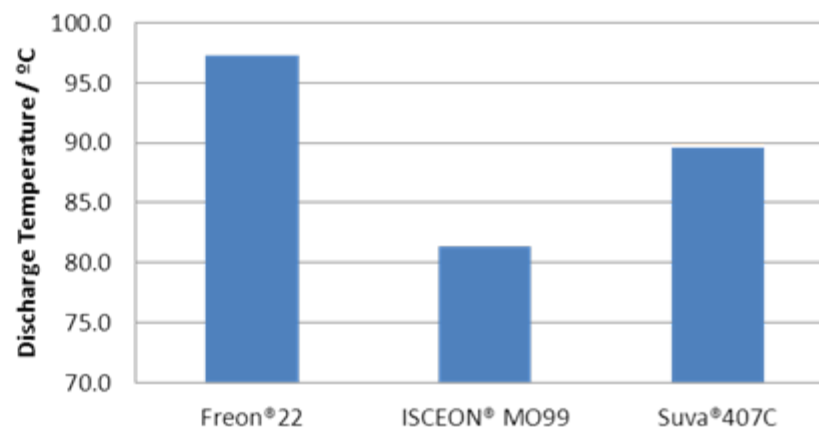
C.O.P. Comparison



Condensing Pressure Comparison



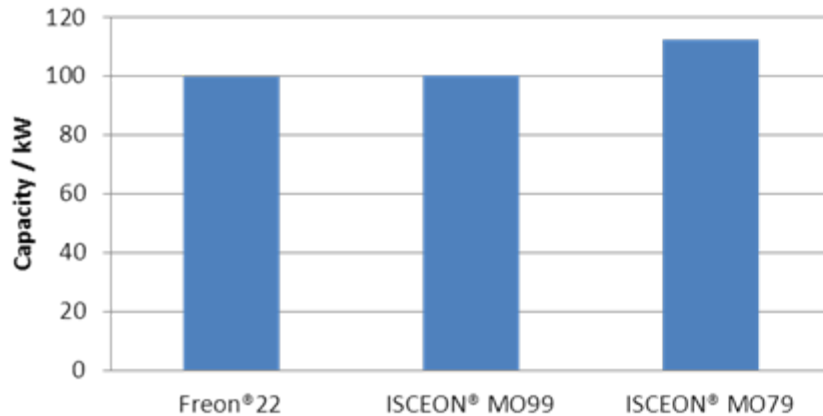
Compressor Discharge Temperature



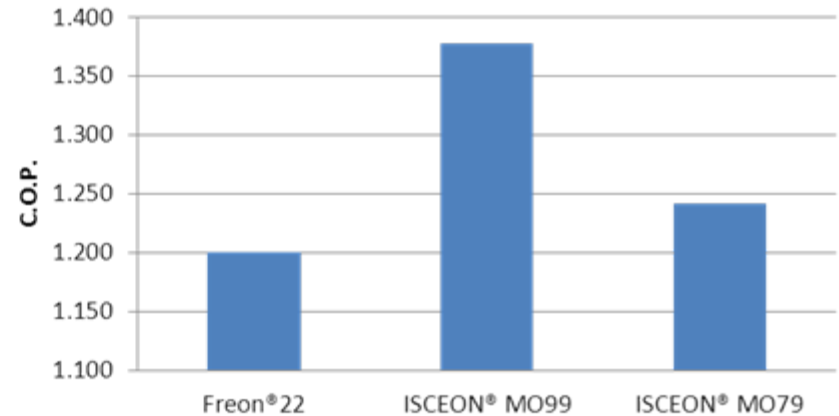
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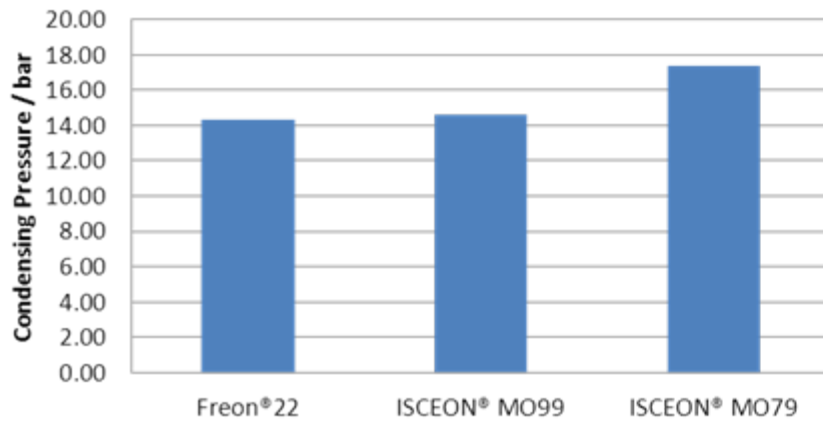
Cooling Capacity Comparison



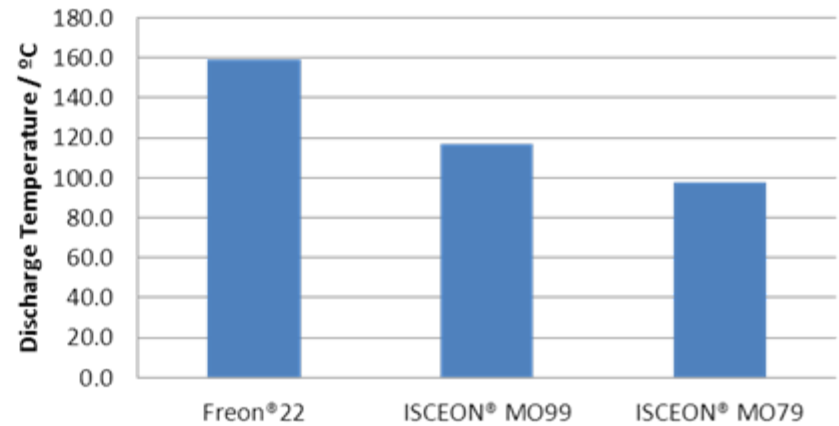
C.O.P. Comparison



Condensing Pressure Comparison



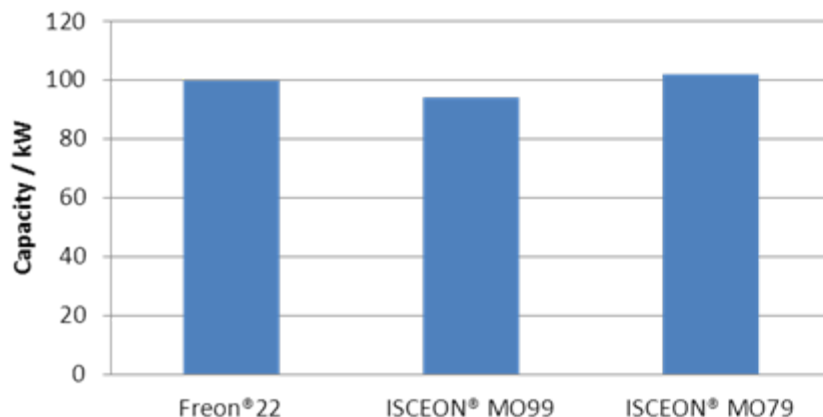
Compressor Discharge Temperature



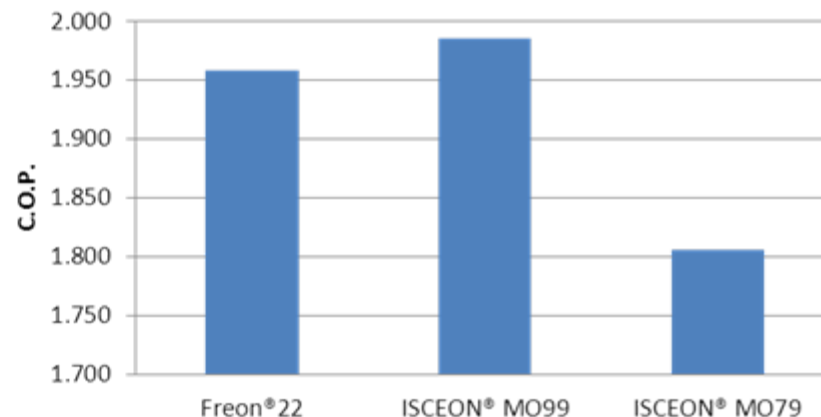
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Refrigerant Comparison – Medium Temperature (-15°C Evap Temp)

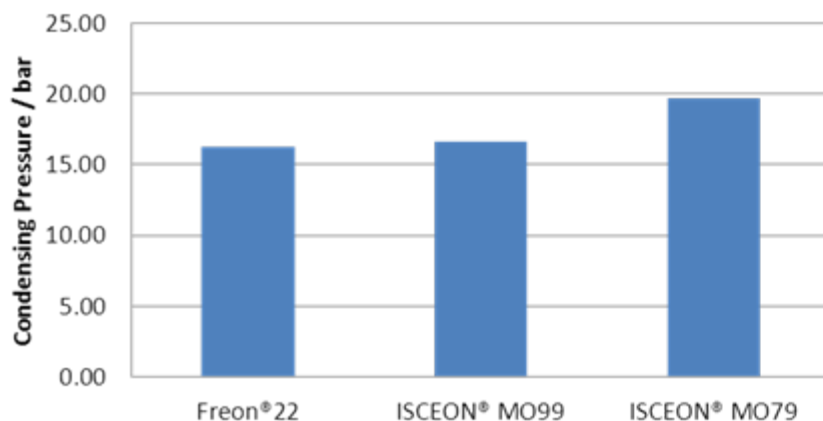
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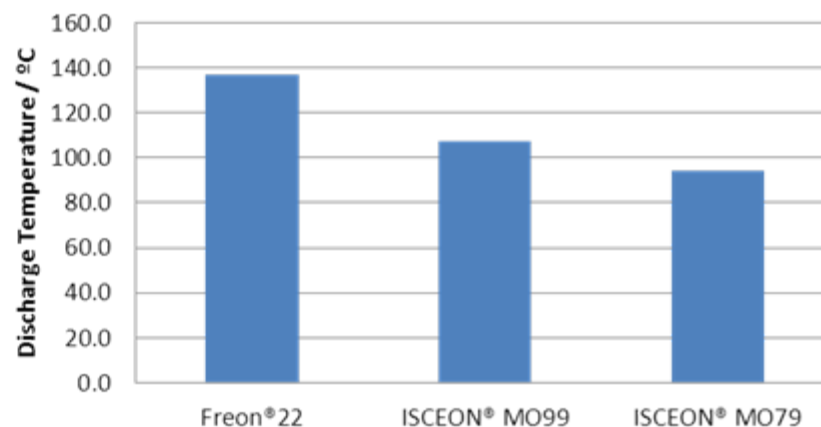
C.O.P. Comparison



Condensing Pressure Comparison



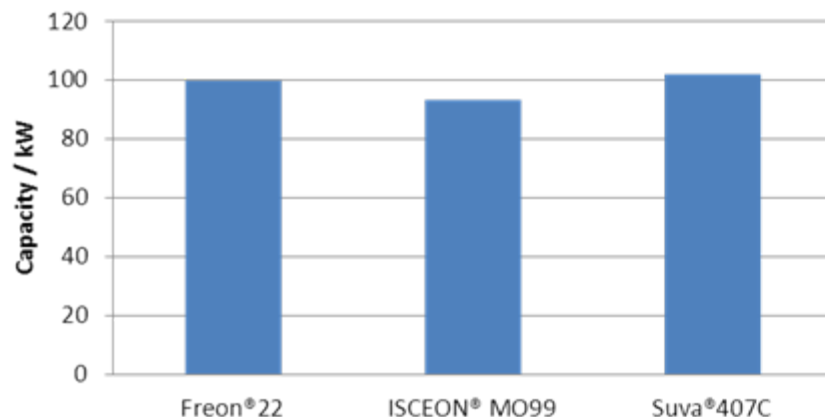
Compressor Discharge Temperature



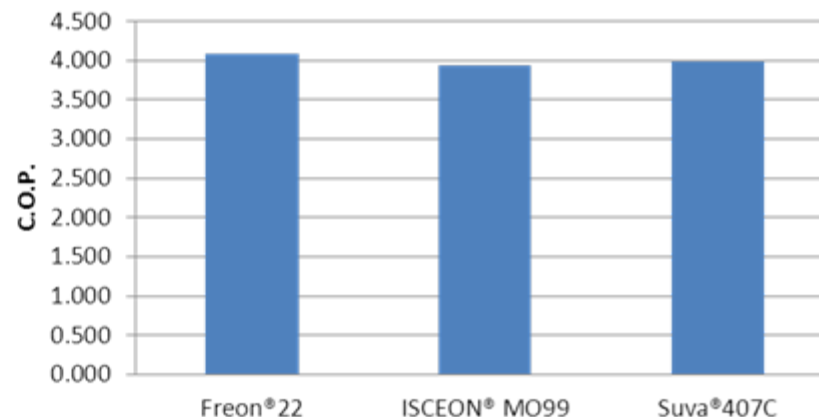
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Refrigerant Comparison – DX Chillers

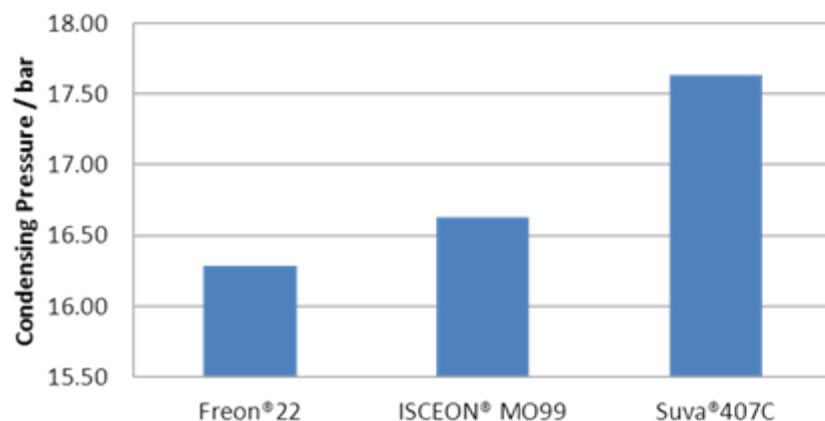
Cooling Capacity Comparison



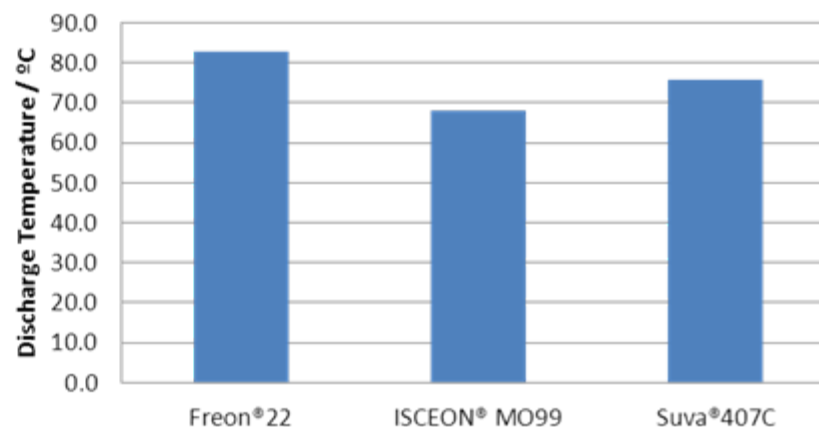
C.O.P. Comparison



Condensing Pressure Comparison



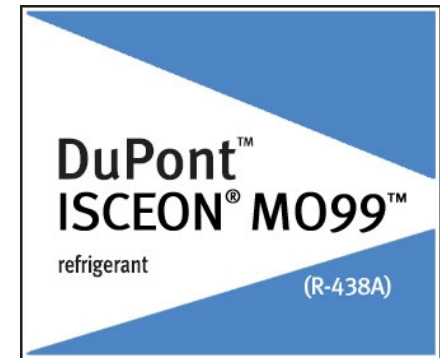
Compressor Discharge Temperature



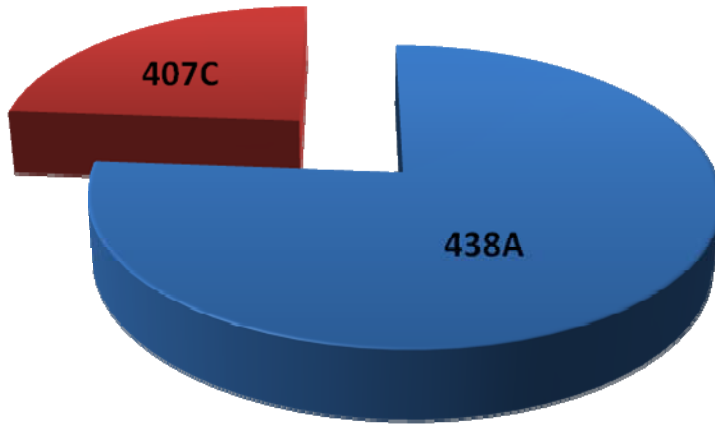
Evaporating Temperature = 5°C, Condensing Temperature = 45°C,
Total Subcool = 7K, Total Superheat = 7K

ISCEON® MO99 refrigerant: THE BASICS

- **ASHRAE #:** R-438A
- **HFC blend:** Zero ozone depletion
- **GWP:** 1890 (SAR)
- **ASHRAE safety:** A1 non-flammable
- **UL:** Certified
- **Glide:** 3-4K
- **Can be topped off while servicing (do not mix with R-22)**
- **Compatible with MO, AB, and POE lubricants**
- **Approved by Bitzer, Emerson (Copeland® Discus® LT/MT supermarket) and Carrier for Chillers**



MO99™ – The #1 Choice for Contractors



Contractors select a refrigerant that.....

- Delivers performance similar to R-22
 - Equivalent efficiency
 - Slight capacity decrease
- Allows easy conversion
 - No oil change in most systems
- Proven in the field
 - Thousands of retrofits
 - OEM-specified

BT data centre retrofitted to ISCEON®MO99



- Data Center of BT Group Plc in West London
- 11 R22-GEA Denco close control systems, each 74kW capacity
- Service Contractor: Temperature Control Ltd. Manchester
- First step: Retrofit of one 17-years-old unit to ISCEON®MO99
 - Closely match of pressure, temp., enthalpy and mass flow
 - One single oil-change to POE before the retrofit
 - R22-removed, all critical seals replaced, filter drier changed
 - Finally minimal adjustment of TXV
- All 11 systems now retrofitted to MO99, due to the positive experiences

On site Refrigerant Conversion for HVAC-Equipment



Carrier completed a rigorous evaluation of 17 different retrofit refrigerant solutions and selected ISCEON®MO99 (R438A) as their #1 and only choice for their service offering!

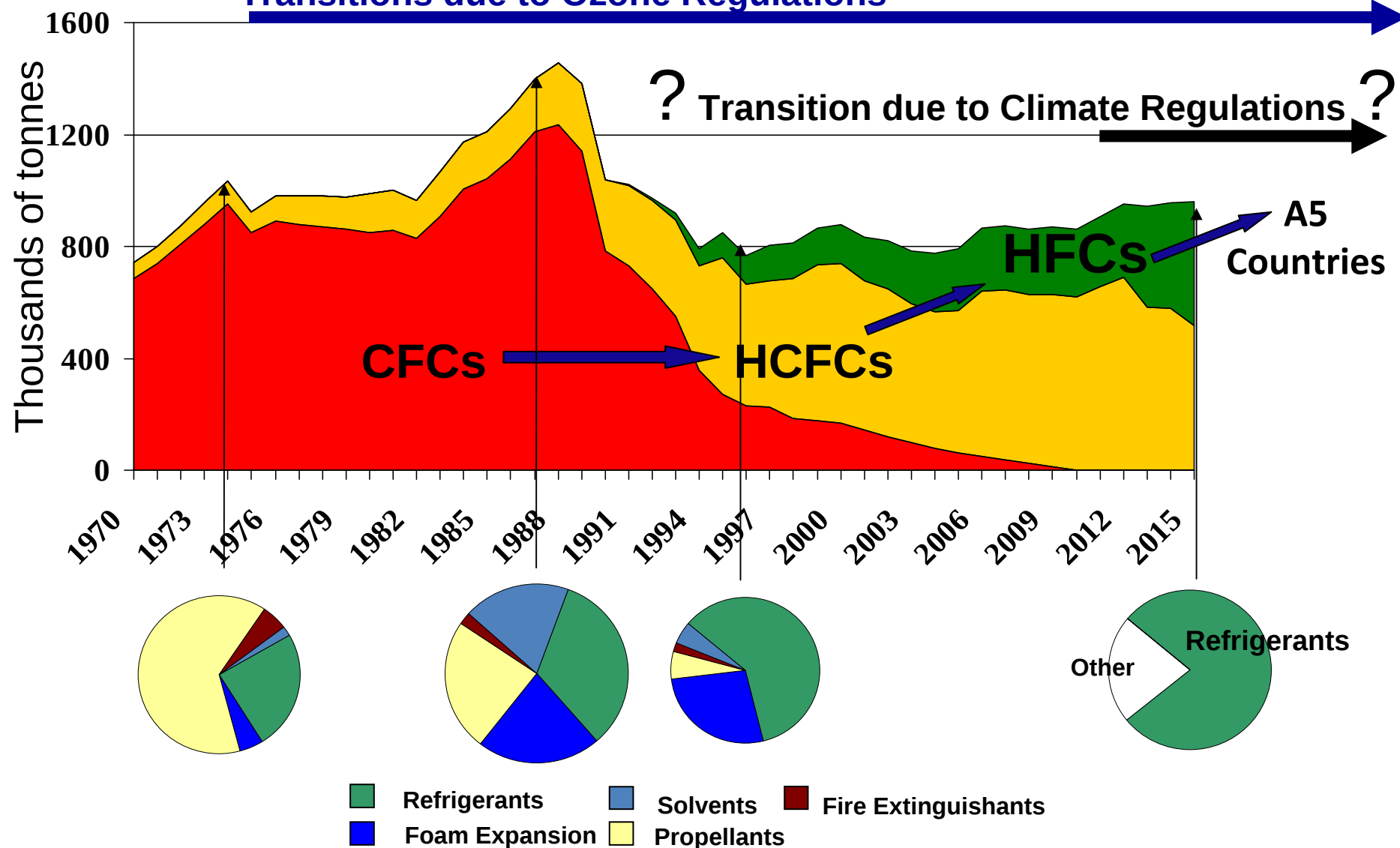
Roof-Top Heat Pump in Phoenix



ISCEON® MO99 - Retrofit of R-22 roof-top heat pump in Phoenix. North Valley Mechanical converted over 50 units to R-438A until April 2012. Service company is very satisfied with the easiness of retrofit and the performance after.

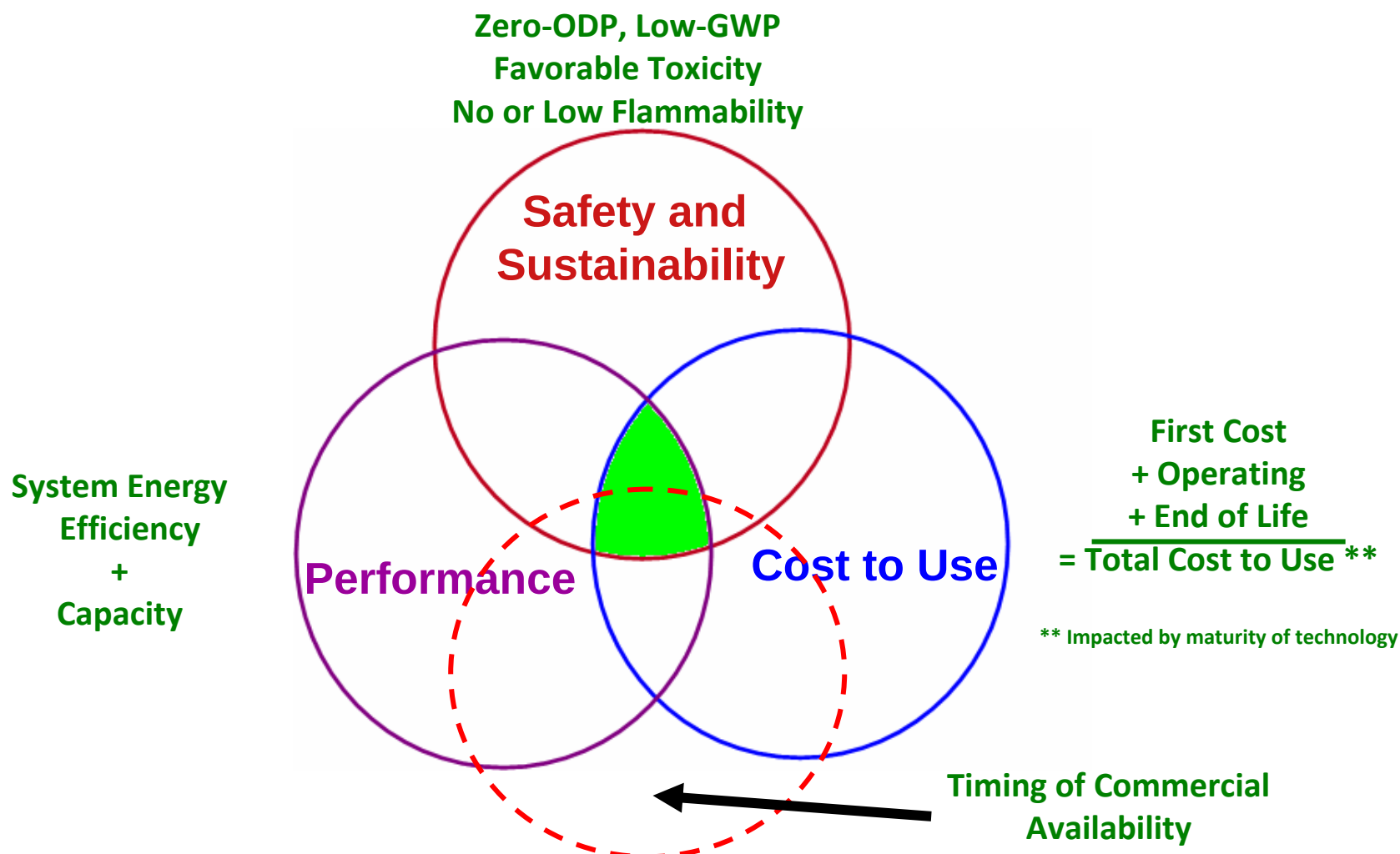
Estimated Global Fluorochemical Consumption

Transitions due to Ozone Regulations



Refrigerant Selection

Best Balance of Properties for each Application



What are “HFOs” ?

CFC Chloro-Fluoro-Carbon

HCFC Hydro-Chloro-Fluoro-Carbon

HFC Hydro-Fluoro-Carbon

HFO Hydro-Fluoro-Olefin

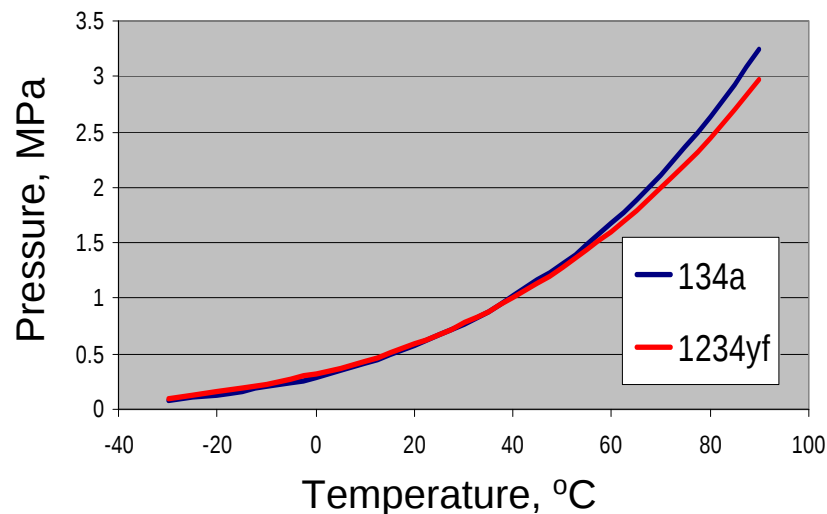
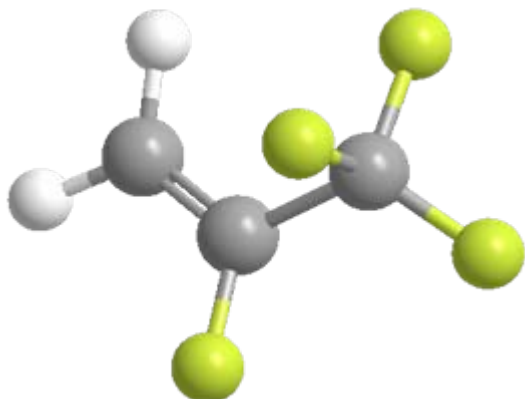
HFO-1234yf $\text{CF}_3\text{CF}=\text{CH}_2$

Unique properties:

- ✓ Stable in operating system
- ✓ Not stable in atmosphere = low GWP
- ✓ Efficient performance

HFO-1234yf ($\text{CF}_3\text{CF}=\text{CH}_2$)

- GWP 4
- Same operating conditions as 134a (similar P/T curve)
- Thermally stable under extreme use conditions
- Cooling capacity and energy efficiency comparable to R-134a
- **Mildly** flammable



	<u>R-134a</u>	<u>HFO-1234yf</u>
Formula	CH_2FCF_3	$\text{CF}_3\text{CF}=\text{CH}_2$
Molecular Weight	102	114
ODP	0	0
GWP ₁₀₀ (AR4)	1430	4
T Critical Point	102 °C	95°C
Boiling Point	-26°C	-29°C

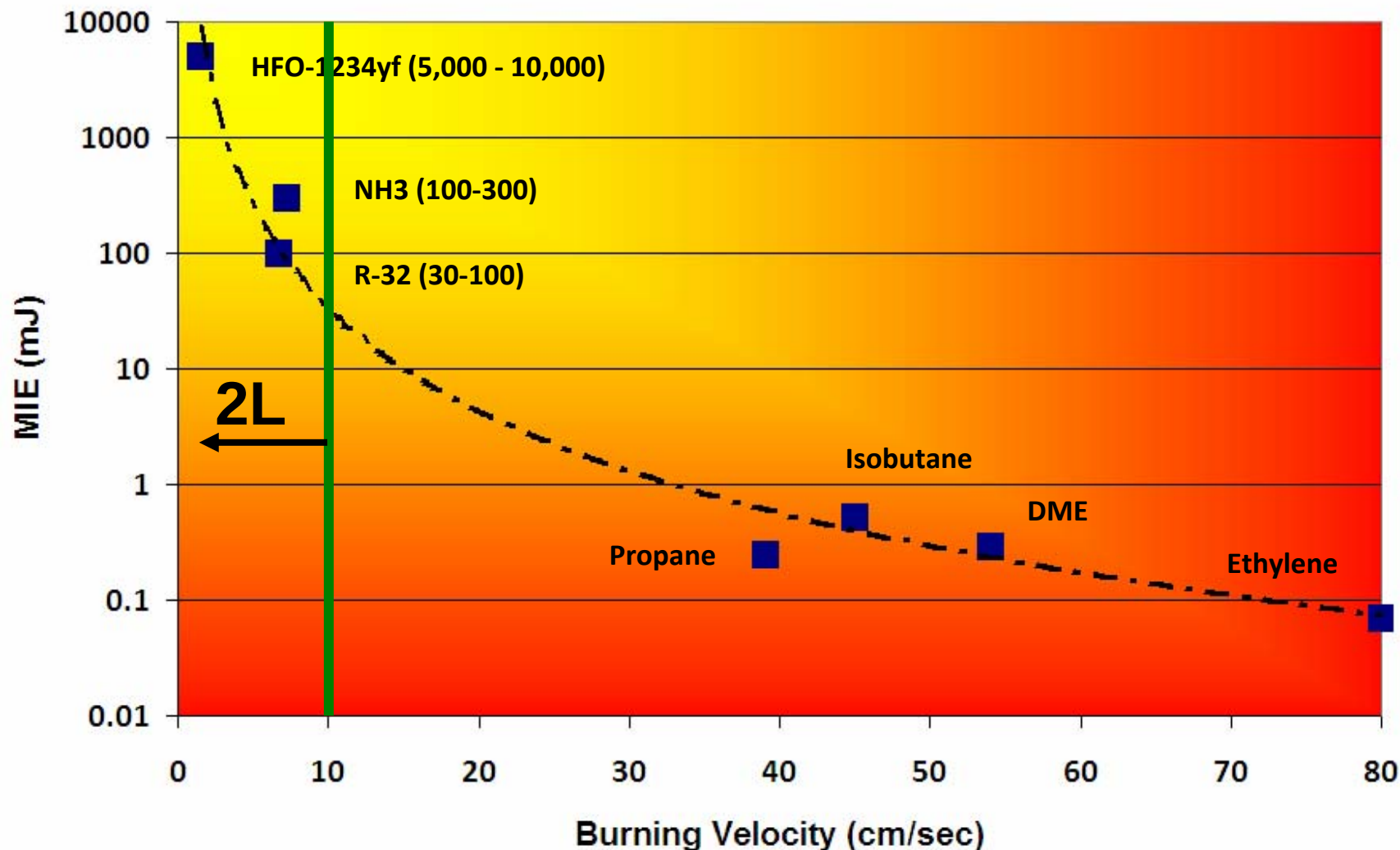
Auto OEM industry – HFO-1234yf

- ✓ **SAE International – HFO-1234yf accepted for use in automotive AC**
 - **Safe for use; low environmental impact**
- ✓ **HFO-1234yf selected by Auto OEMs globally to meet EU MAC Directive**

ASHRAE Product Safety Considerations

ASHRAE Classification		Examples:	
Highly Flammable (3)	A3	Propane	A3
	B3	Isobutane	A3
Flammable (2)	A2	R-152a	A2
Mildly Flammable (2L)		HFO-1234yf	2L
Practically Non-Flammable (1)	A1	R-134a	A1
	Low Toxicity (A)	Higher Toxicity (B)	

Correlations of Burning Velocity and MIE



HFO-1234yf High Minimum Ignition Energy – Difficult to Ignite

Standards Activity in Europe

ASHRAE Class 2L



- **Safety standards -- updating for 2L:**

- ISO-5149 Complete 2012
- IEC-60335-2-40 Revisions underway

- **Impact on market:**

- Larger charge sizes allowed than Class 2 or 3 refrigerants (e.g. hydrocarbons)
- Allows 2L use in small to medium A/C and refrigeration systems (e.g. Self contained and condensing units)
 - charge limits may be set based on room size

DuPont™ Opteon® Refrigerants

- The *Optimal* balance of properties
- GWP reduction over current HFCs
- Improved environmental sustainability
- Efficient performance

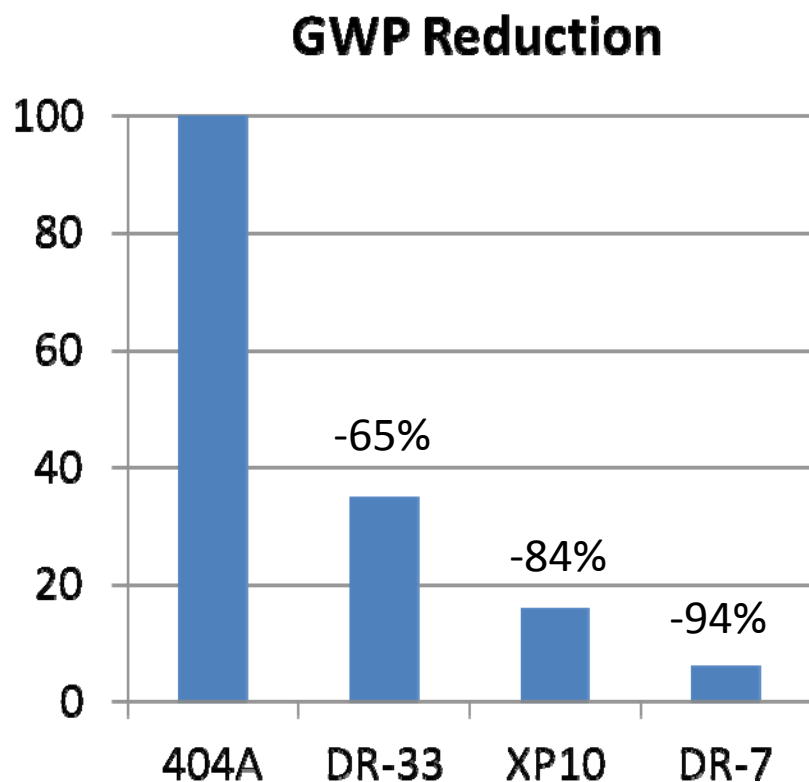
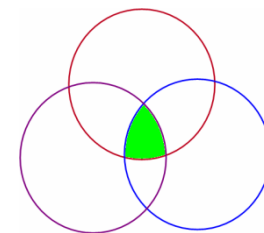


DuPont Next Generation Refrigerants for Stationary AC & R Leading Candidates

Current Refrigerant		Leading Lower GWP Candidates - HFO based			
		Non-flammable		Mildly flammable	
		ASHRAE Class 1		ASHRAE Class 2L	
		Name	GWP	Name	GWP
HFC-134a	1430	Opteon™ XP10	~ 600	Opteon™ yf	4
HFC-404A	3922	DR-33	~ 1400	DR-7	~ 250
HFC-410A	2088			DR-5	~ 500
HCFC-22	1810			DR-3	~ 150
HCFC-123	77	DR-2	~ 10		

Opteon® Low GWP Replacements for R-404A

Leading Candidates



DR-33

- GWP ~ 1400; 65% reduction vs R-404A
- Close performance match to R-404A
- Non-flammable; for retrofit and new systems

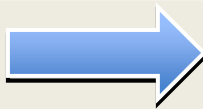
XP10

- GWP ~ 600; 84% reduction vs R-404A
- Close performance match to R-134a; for retrofit and new systems
- Non-flammable; preferred for hybrid CO2 cascade systems

DR-7

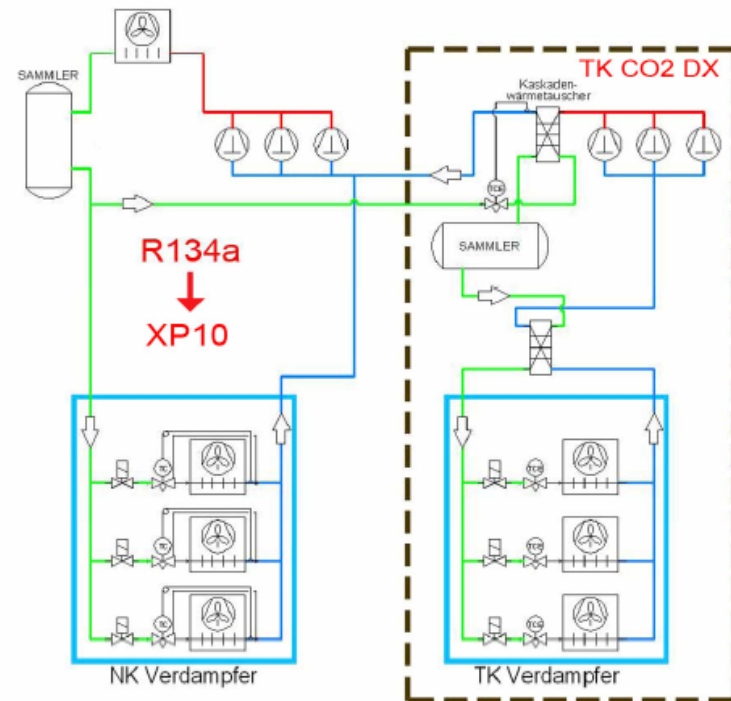
- GWP ~ 250; 94% reduction vs R-404A
- Close performance match to R-404A
- Mildly flammable (ASHRAE Class 2L expected)
- For smaller charge size equipment (condensing units, self-contained)

Stationary AC&R Application Development

Application	Current	Near-Term	Long-Term
Commercial Refrigeration	R-134a	R-134a	HFOs, XP10
	R-404A/507	R-407A	DR-7, DR-33
	CO ₂	CO ₂	CO ₂
DX Air Conditioning/Heat Pumps	R-410A		DR-5, R-32
Chiller	R-134a	R-134a	HFOs, XP10
	R-123 (Past)		DR-2

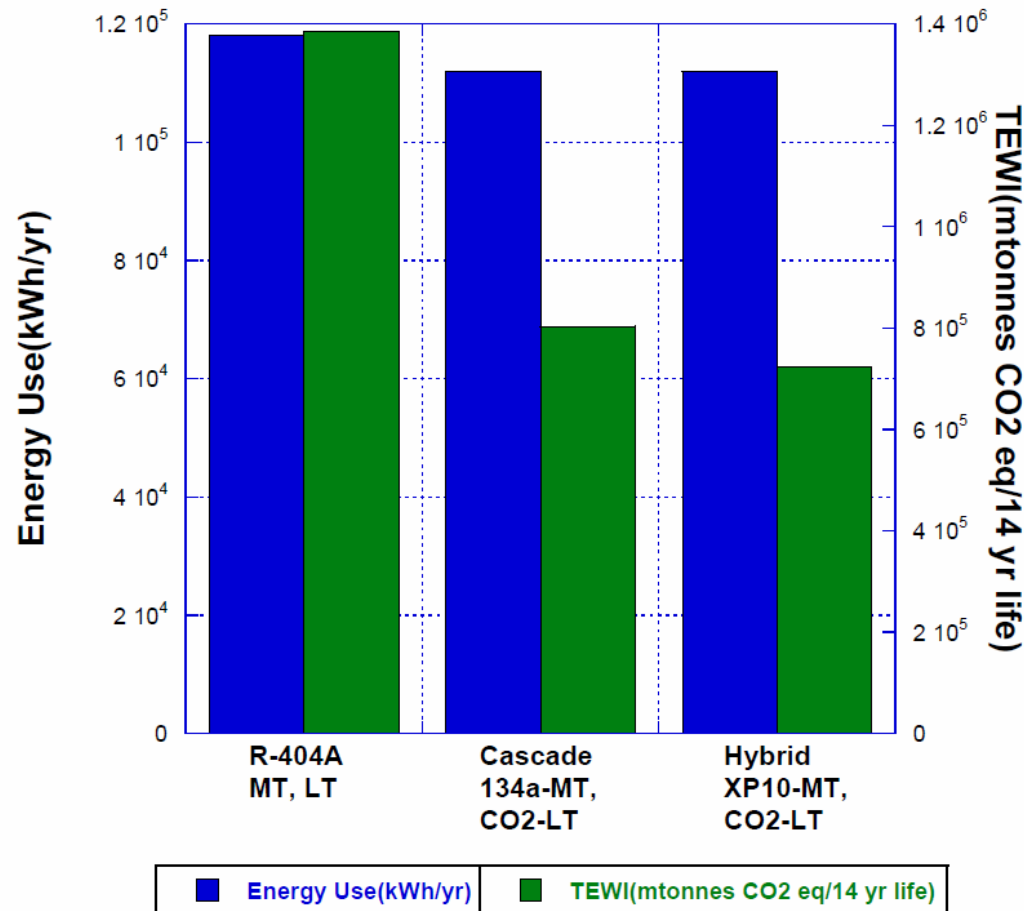
XP10 Evaluation in Supermarket - Hybrid System

- Retrofitted from R-134a Medium Temp; CO₂ in Low Temp
- Running for two years



HAUSER
so cool. so beautiful.

Annual Energy Use and TEWI Comparison



TEWI reduced by 48% for XP10-CO2 hybrid system versus R-404A

Albert Heijn Assendelft/ Netherlands

Hybrid System and Heat-Pump

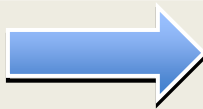


*Coordination by P.W. Vlaskamp
B.V. Refrigeration Consultancy*

*XP10 / CO₂ – Cascade & R134a HP
Installer Company: Frimex TBI*



Stationary AC&R Application Development

Application	Current	Near-Term	Long-Term
Commercial Refrigeration	R-134a	R-134a	HFOs, XP10
	R-404A/507	R-407A	DR-7, DR-33
	CO ₂	CO ₂	CO ₂
DX Air Conditioning/Heat Pumps	R-410A		DR-5, R-32
Chiller	R-134a	R-134a	HFOs, XP10
	R-123 (Past)		DR-2

Reach-In Freezer Drop-in Test – DR-7, DR-33

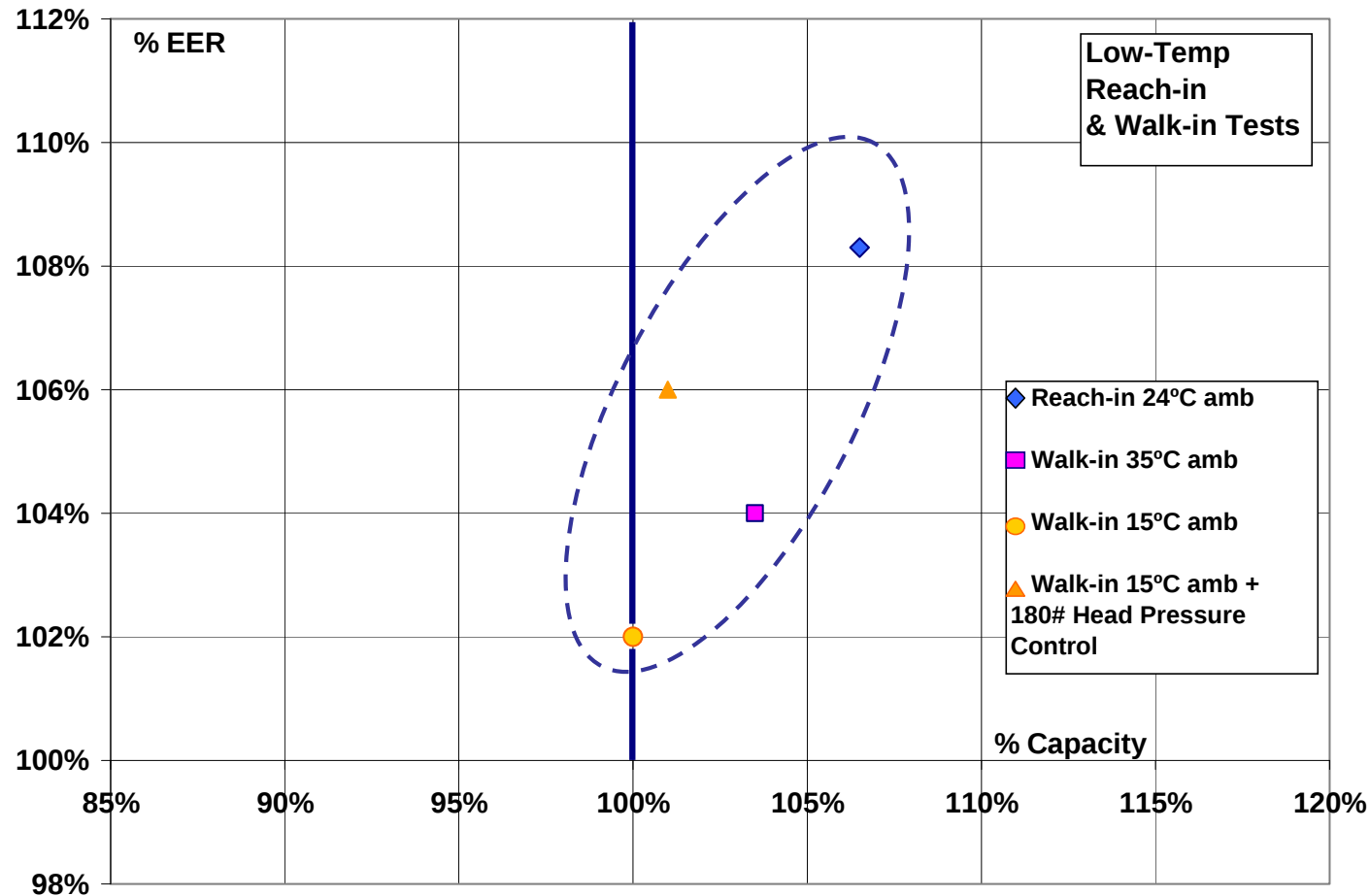
	Energy Consump (kWhr/day)	Energy Cons Rel to R404A
Ambient T = 32°C		
R404A	33.46	100%
DR-7	30.81	92%
DR-33	32.16	96%
Ambient T = 24°C		
R404A	25.11	100%
DR-7	23.91	95%
DR-33	25.00	100%
Ambient T = 21°C		
R404A	23.39	100%
DR-7	22.62	97%
DR-33	23.41	100%



Energy consumption equivalent or lower than 404A

Source: DuPont Systems Lab Test Results

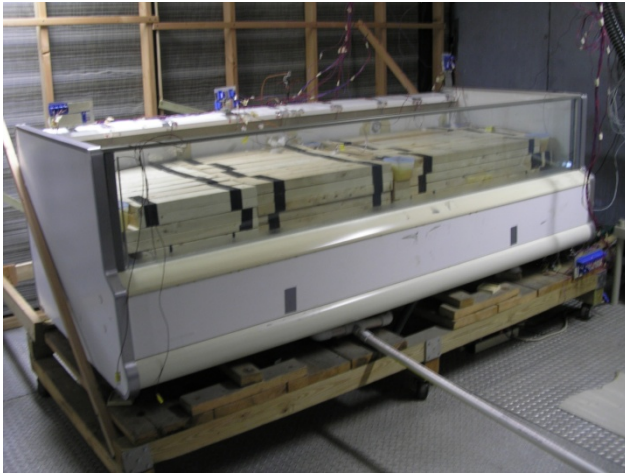
Low Temp Reach-in & Walk-in Test Results – DR-7



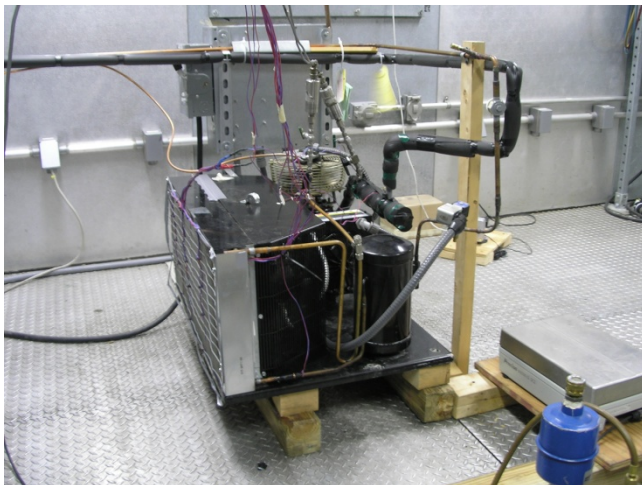
Energy efficiency and capacity superior to 404A

Source: DuPont testing partner system test lab results – data used with permission

Condensing Unit Low Temp Test



Open Display Case in Indoor Room



Condensing Unit in Outdoor Room

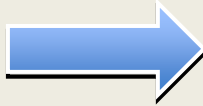
- 2.5 m open frozen food display case designed for R-404A, fully loaded with food simulator
- Reciprocating compressor with POE 32 oil
- Refrigerant charge size ~3.8 kg, adjusted based on liquid density
- Tested per ASHRAE Standard 72-2005
- Tested R-404A and DR-33 at two ambient temps: 28°C and 35°C
- Only minor TXV adjustment made (1.6 turns closed)
- Average food simulator temp controlled at -16°C, average evaporator temp -34°C

Condensing Unit Test Results

- DR-33 showed 3-4% lower energy consumption
- similar pressures and compression ratio
- modest increase in discharge T and slightly lower mass flow rate

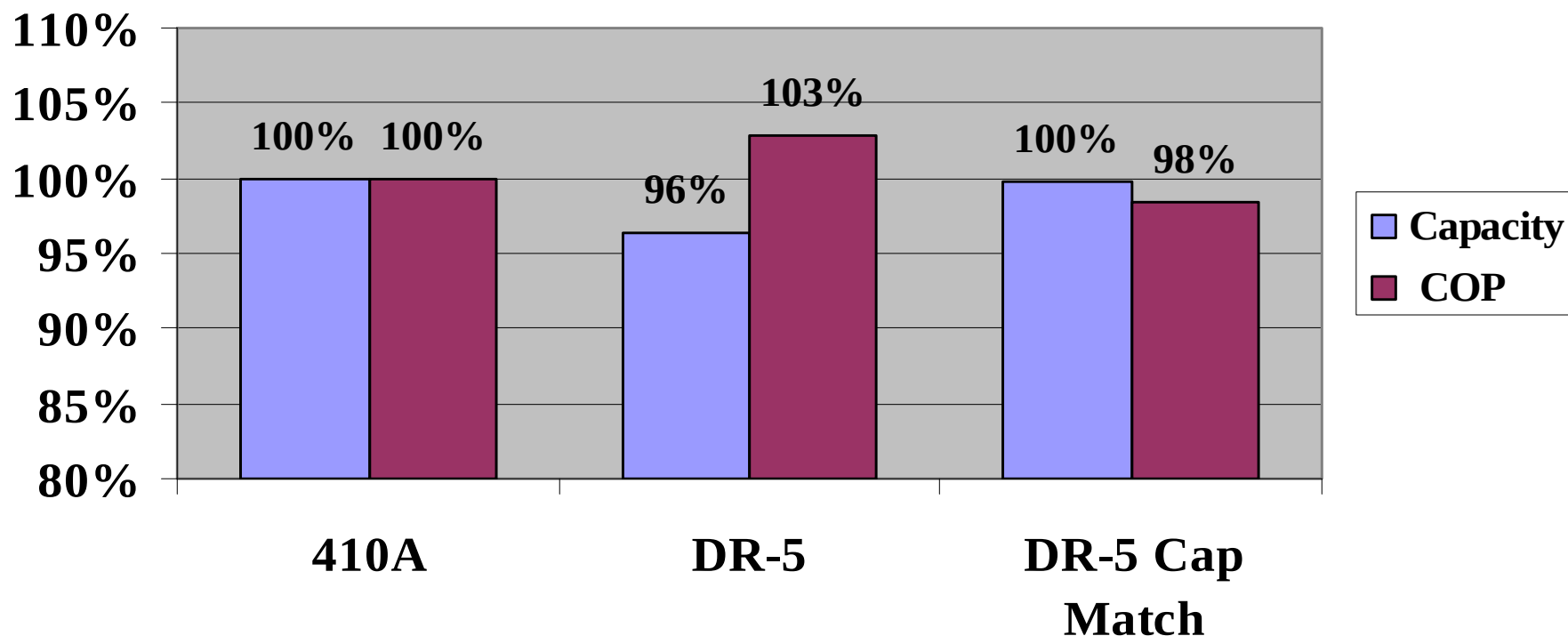
	Energy Consump (kWhr/day)	Energy Cons Rel to R404A	Mass Flow Rate (kg/hr)	Suct Press (kPa)	Disch Press (kPa)	Comp Ratio	Comp Disch Temp (°C)
Ambient T = 28°C							
R404A	31.59	100%	32	112	1438	13	78
DR-33	30.54	97%	26	104	1407	14	83
Ambient T = 35°C							
R404A	32.42	100%	33	127	1722	14	87
DR-33	31.21	96%	26	115	1685	15	92

Stationary AC&R Application Development

Application	Current	Near-Term	Long-Term
Commercial Refrigeration	R-134a	R-134a	HFOs, XP10
	R-404A/507		DR-7, DR-33
	CO ₂	CO ₂	CO ₂
DX Air Conditioning/Heat Pumps	R-410A		DR-5, R-32
Chiller	R-134a	R-134a	HFOs, XP10
	R-123 (Past)		DR-2

Cooling Comparison: DR-5 vs R410A

7.4 kW R-410A inverter mini-split



Performance similar to R-410A

Source: "Reduced GWP Refrigerant Evaluations for AC and Heat Pump Applications"; ICACR Pyongyang, Korea 7 July, 2011; Thomas Leck – DuPont Refrigerants, Younghwan Ko – LG Electronics, Inc, Jongchul Ha – LG Electronics, Inc

DuPont™ Opteon® Refrigerants

Commercial Timing for Stationary AC & R

HFO Production

**Opteon® yf
(HFO-1234yf)**

Interim Production
(Focus on MAC + ACR Testing)

Large Scale Commercial
Production

DR-2

Pilot Plant

Large Scale Commercial
Production

Market Development/Demand for Stationary Applications

**Opteon® yf,
DR-2,
HFO Blends
(e.g. DR-5,
DR-7, XP10)**

Application Development

Commercial Demand

2012 2013 2014 2015 —————> 2020 +

DuPont™ Opteon® Refrigerants

Next Steps

- ✓ Monitor F-Gas revision and assess market interest and timing for Stationary AC & R
- ✓ Build/expand production capacity for HFO-1234yf to support new F-Gas Regulation requirements
- ✓ Continue application development for Stationary AC & R
- ✓ Assess Total Cost of Ownership (TCO) versus other options
- ✓ Continue to develop codes & standards for 2L refrigerants (smaller charges)

Conclusions

- o A Full Range of Non-Ozone Depleting HFC Refrigerants

Thank You



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