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Open Seminar

Lubricants Optimized for use with Low Global Warming Potential Refrigerants

Polyol Ester Lubricants Designed for use with R-32 and related Low GWP HFC/HFO Blends

2014 Winter Conference, NY, NY

Learning Objectives

1. Understand the importance of matching the right lubricant and refrigerant to optimize system operation, energy consumption and reliability.
2. Describe the important performance properties/criteria for a refrigeration lubricant.
3. Describe the difference between miscibility and solubility of lubricant/refrigerant mixtures.
4. Recognize that not all systems are the same when it comes to choosing lubricants for a particular refrigerant.
5. Understand the differences between the various lower GWP refrigerants.
6. Understand how lubricant-refrigerant interactions affect the overall Life Cycle Climate Performance (LCCP).

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Chemtura Corporation

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- John Bayusik
- Jeff Hutter
- Dale Carr

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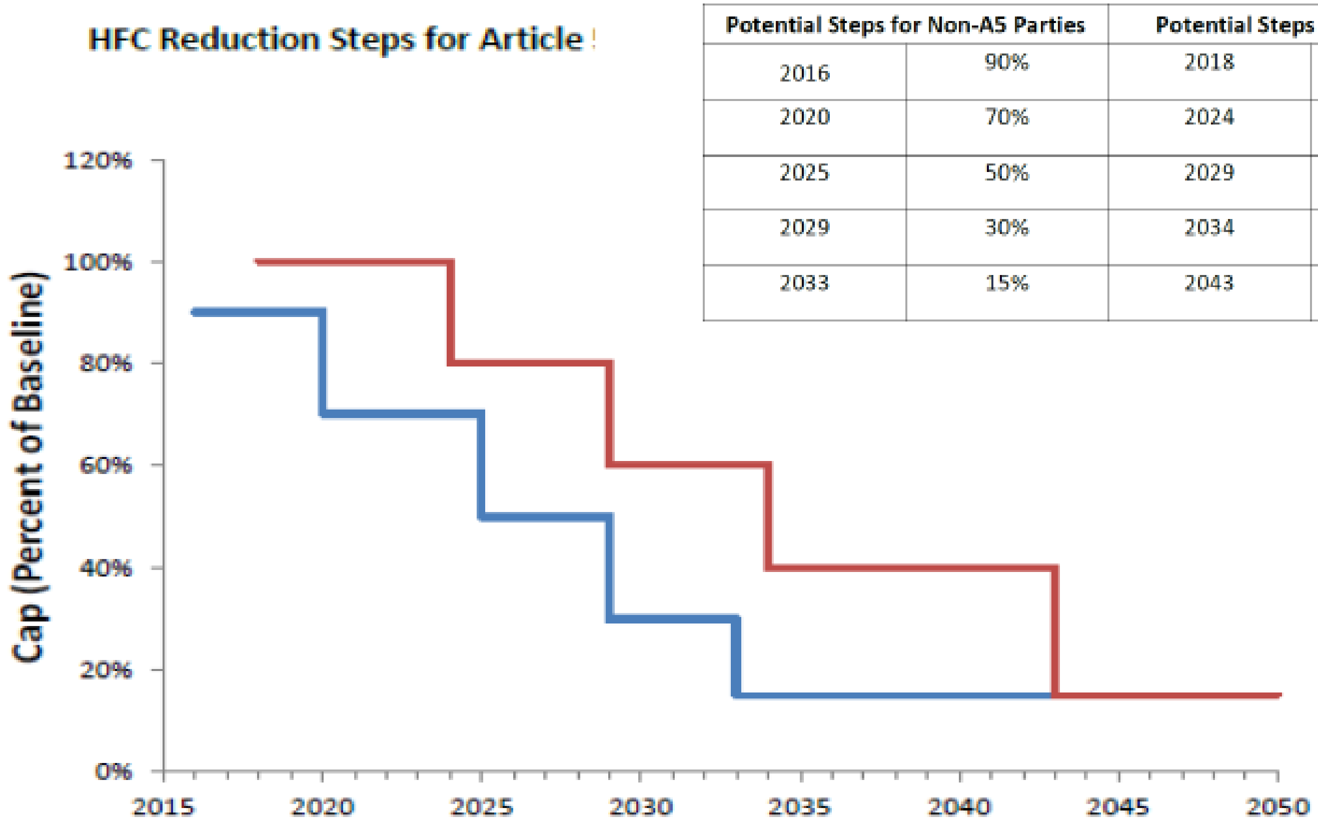
Outline/Agenda

- Accelerating the phase out of HFC refrigerants.
- R-22 and R-410A replacements for AC.
- A requirement for new lubricants?
- Can the lubricant improve system COP and EER?
- Refrigerant/lubricant miscibility
- Working fluid solution viscosity
- Conclusions

2012 Montreal Protocol HFC Amendment (NAFTA)



Potential Steps for Non-A5 Parties		Potential Steps for A5 Parties	
2016	90%	2018	100%
2020	70%	2024	80%
2025	50%	2029	60%
2029	30%	2034	40%
2033	15%	2043	15%

Refrigerant Options for R-22 and R-410A Replacement in AC

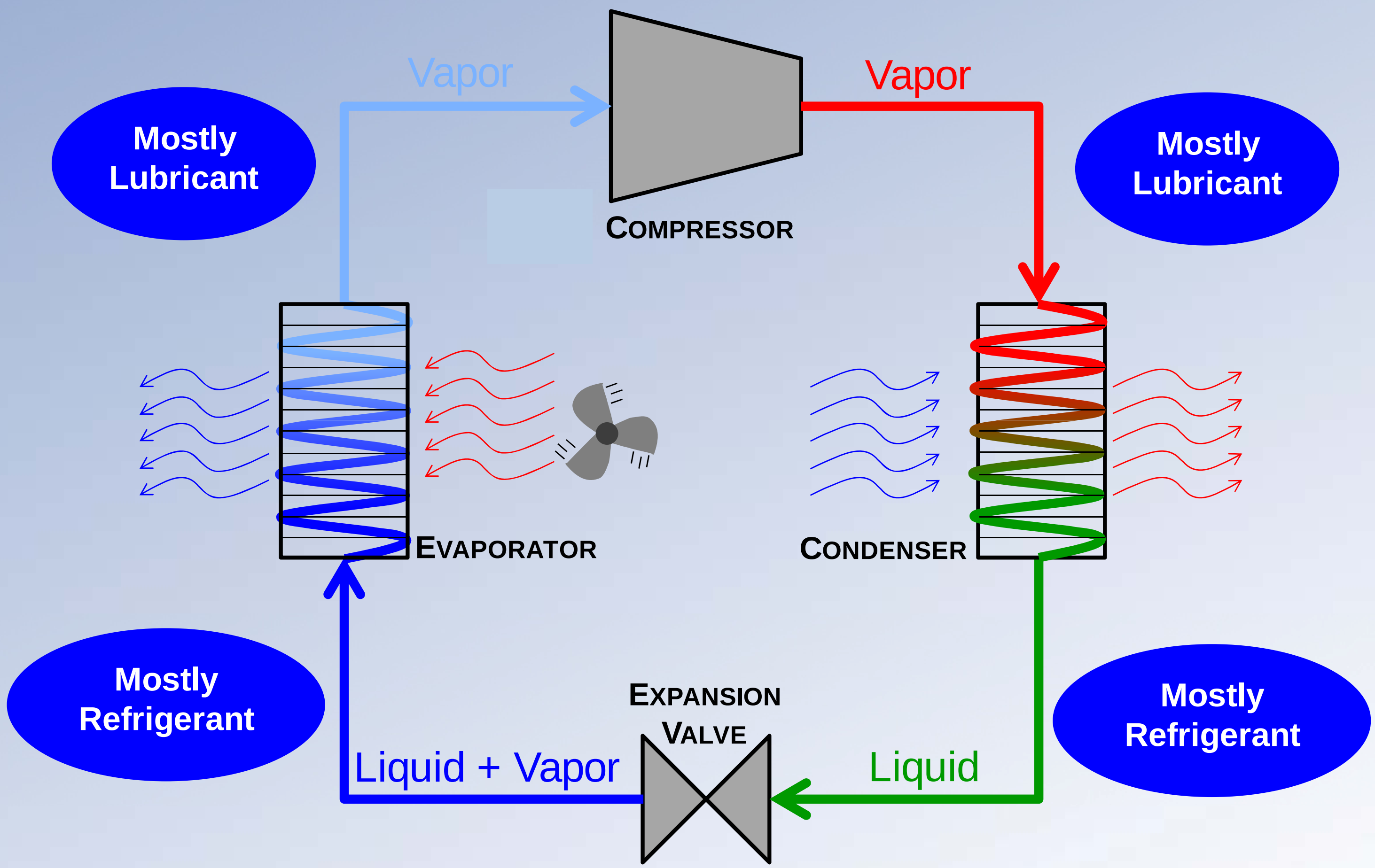
Refrigerant	Type	ODP	GWP	ASHRAE Safety Group
R-22	HCFC	0.05	1810	A1
R-410A	HFC Blend	0	2080	A1
R-32	HFC	0	675	A2L
L41a, L41b, ARM-70a, D2Y60, DR-5, HPR1D	HFC/HFO or HFC/CO2/HFC Blends	0	275-700	A2L*
R-1234ze R-1234yf	HFO	0	4-6	A2L
R-600a	Hydrocarbon	0	3	A2
R-290	Hydrocarbon	0	3	A3
R-744	Natural	0	1	A1

R-410A Alternatives

Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP_{100}
R410A	R-744	R-744	100	A1	1
	ARM-70a	R-32/R-134a/R-1234yf	(50/10/40)	A2L*	482
	D2Y60	R-32/R-1234yf	(40/60)	A2L*	272
	DR-5	R-32/R-1234yf	(72.5/27.5)	A2L*	490
	HPR1D	R-32/R-744/R-1234ze(E)	(60/6/34)	A2L*	407
	L41a	R-32/R-1234yf/R-1234ze(E)	(73/15/12)	A2L*	494
	L41b	R-32/R-1234ze(E)	(73/27)	A2L*	494
	R32	R32	100	A2L	675
	R32/R134a	R-32/R-134a	(95/5)	A2L*	713
	R32/R152a	R-32/R-152a	(95/5)	A2L*	647

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2010.

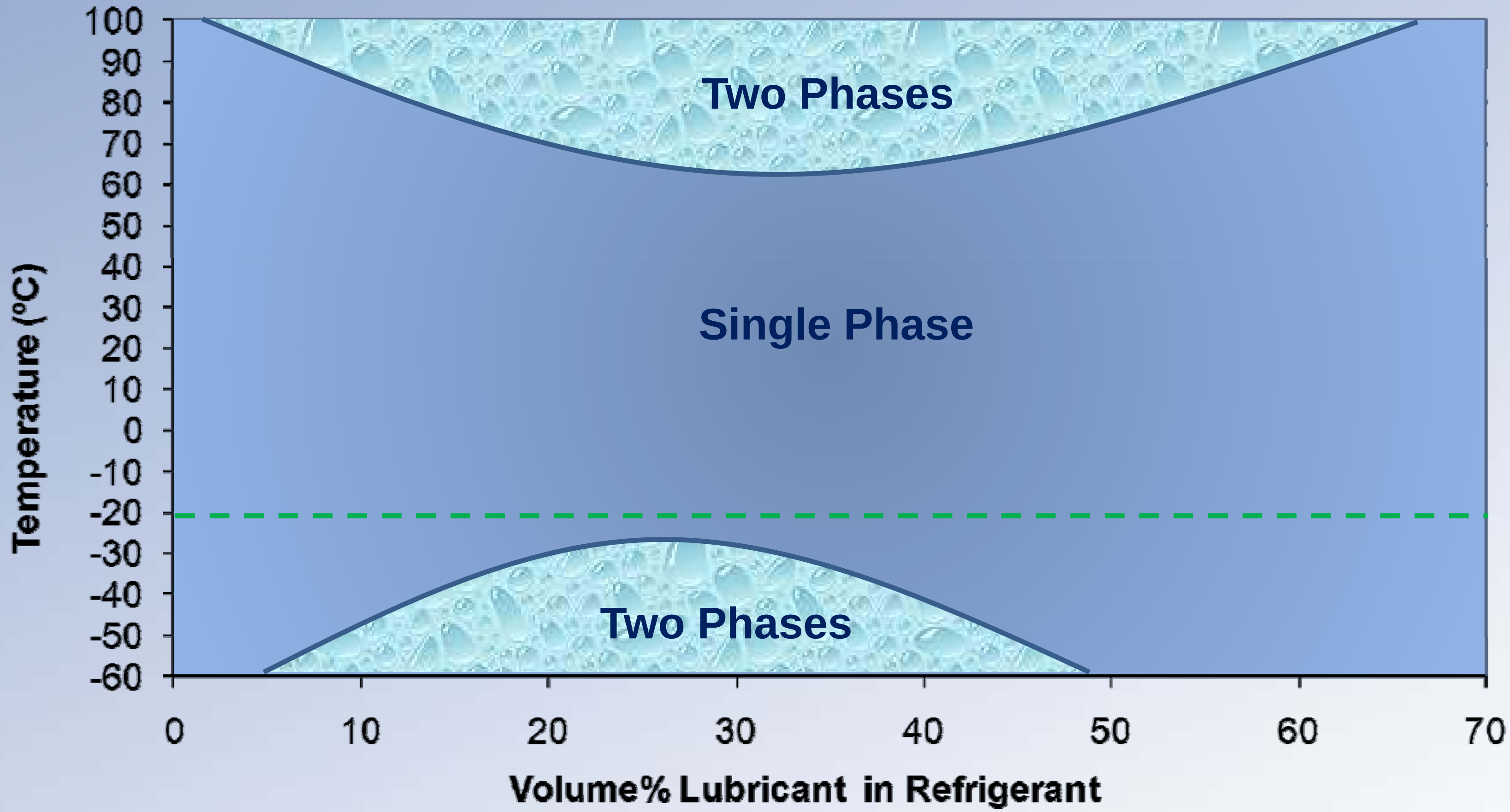
Liquid Composition in a Refrigeration Cycle



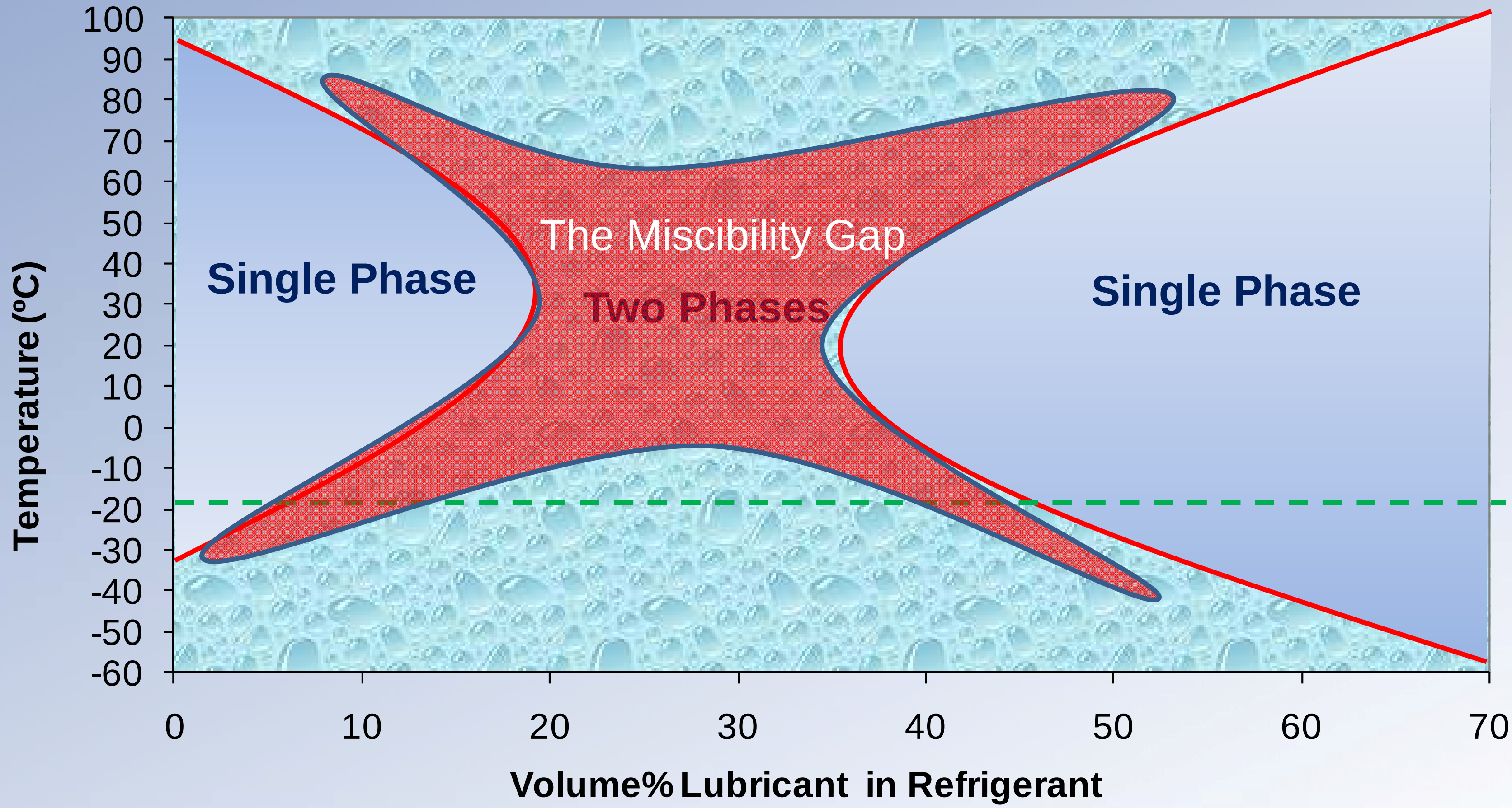
Potential Lubricant Related Issues in Changing from R-410A to R-32

- Significant changes in R-32/lubricant miscibility.
- Greater lubricant viscosity dilution by R-32 refrigerant

Miscibility Profile of a Traditional POE in R-410A

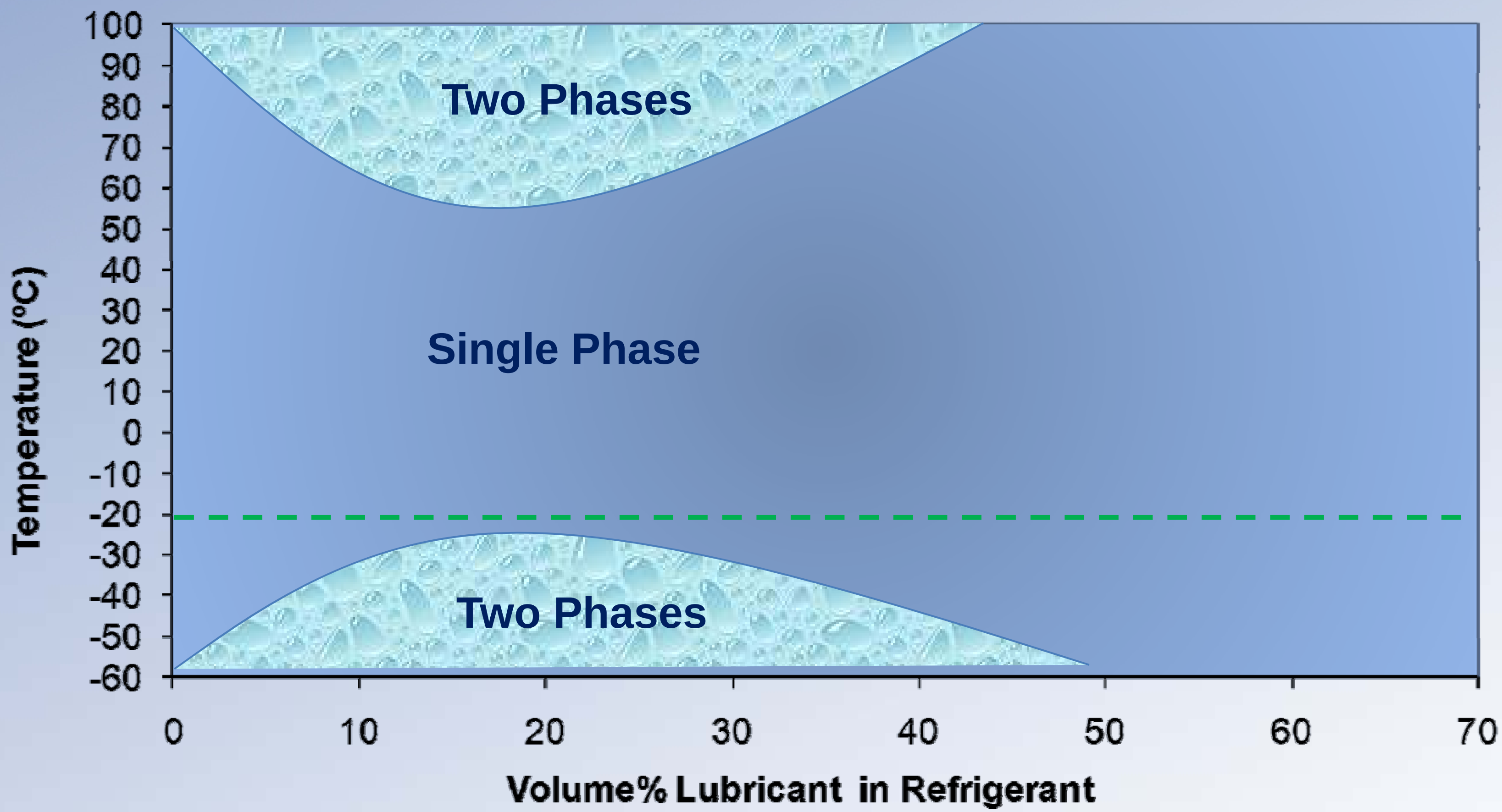


Miscibility Profile of a Traditional POE in R-32

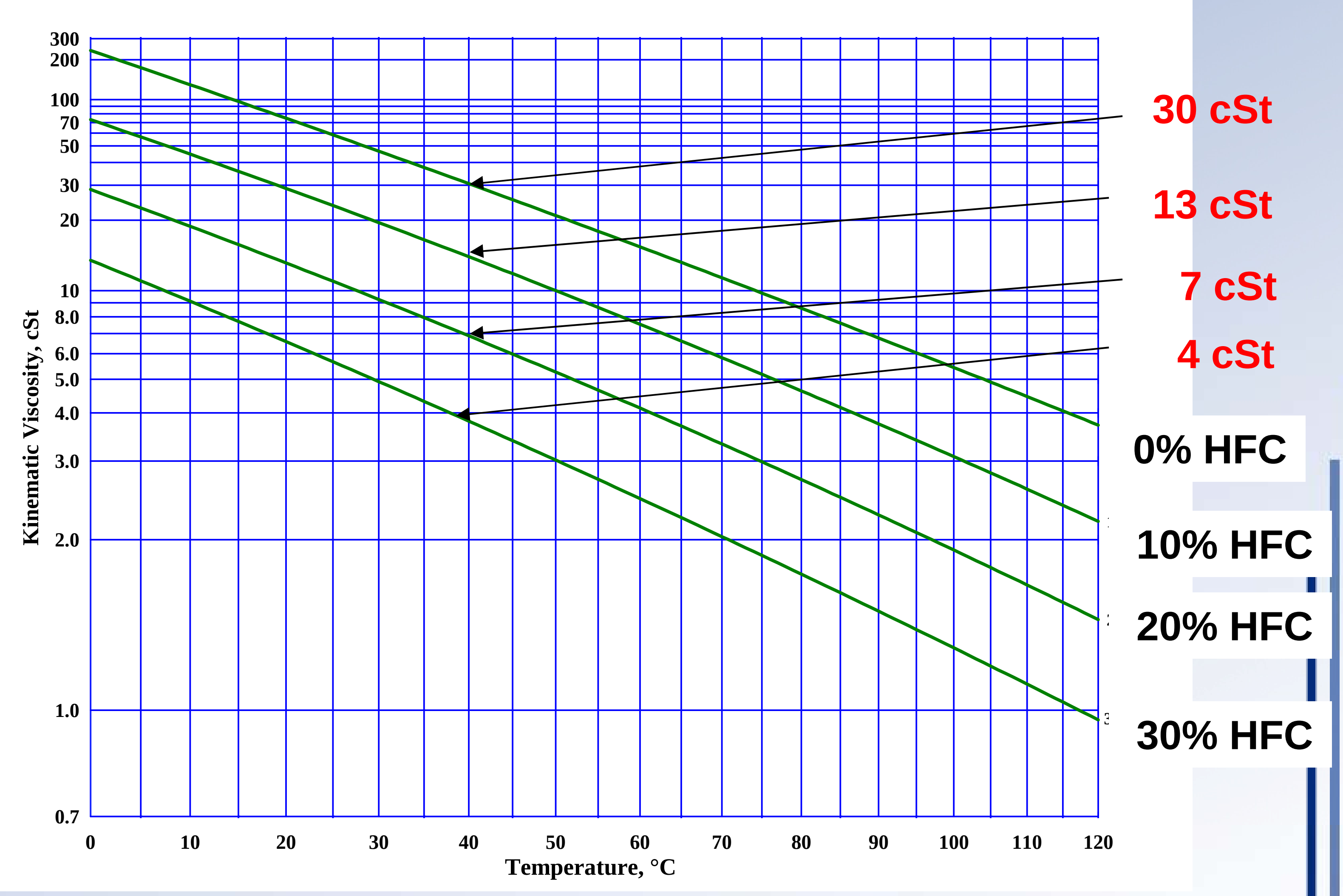


Could the “gap” result in poor oil return and/or decreased HX efficiency?

Miscibility of an ISO 32 Advanced POE with R-32 Refrigerant



Lubricant Viscosity Dilution by Refrigerant



Measuring Thermochemical Properties of Refrigerant/Lubricant Mixtures

Constants

coeff #	Dyn. Visc	Press	Density	Kin. Visc
a1	-1.79446E+01	3.48166E+00	1.27953E+00	-5.10562E+00
a2	1.03941E+01	-1.38944E+02	-1.23123E-03	5.82199E+00
a3	-1.22731E+00	-1.91490E+05	7.29594E-07	-8.20213E-01
a4	-3.21533E+01	-1.09774E+00	-6.84895E-02	-5.90926E+00
a5	1.20719E+01	1.34775E+03	2.44612E-03	2.91606E+00
a6	-1.19664E+00	-2.86484E+05	-4.58195E-06	-3.99393E-01
a7	-1.10460E+02	-5.28900E-01	2.44245E+00	-1.34335E+02
a8	4.18384E+01	2.47810E+02	-1.39472E-02	4.97634E+01
a9	-3.97946E+00	-4.91870E+04	1.88632E-05	-4.64048E+00
rsq	0.9992	0.999709	0.9999	0.9992

Equations of State

$$Log(P) = a_1 + \frac{a_2}{T} + \frac{a_3}{T^2} + Log(\omega)\left(a_4 + \frac{a_5}{T} + \frac{a_6}{T^2}\right) + Log^2(\omega)\left(a_7 + \frac{a_8}{T} + \frac{a_9}{T^2}\right)$$

$$\rho = a_1 + a_2 \mathrm{T} + a_3 \mathrm{T}^2 + \omega\left(a_4 + a_5 \mathrm{T} + a_6 \mathrm{T}^2\right) + \omega^2\left(a_7 + a_8 \mathrm{T} + a_9 \mathrm{T}^2\right)$$

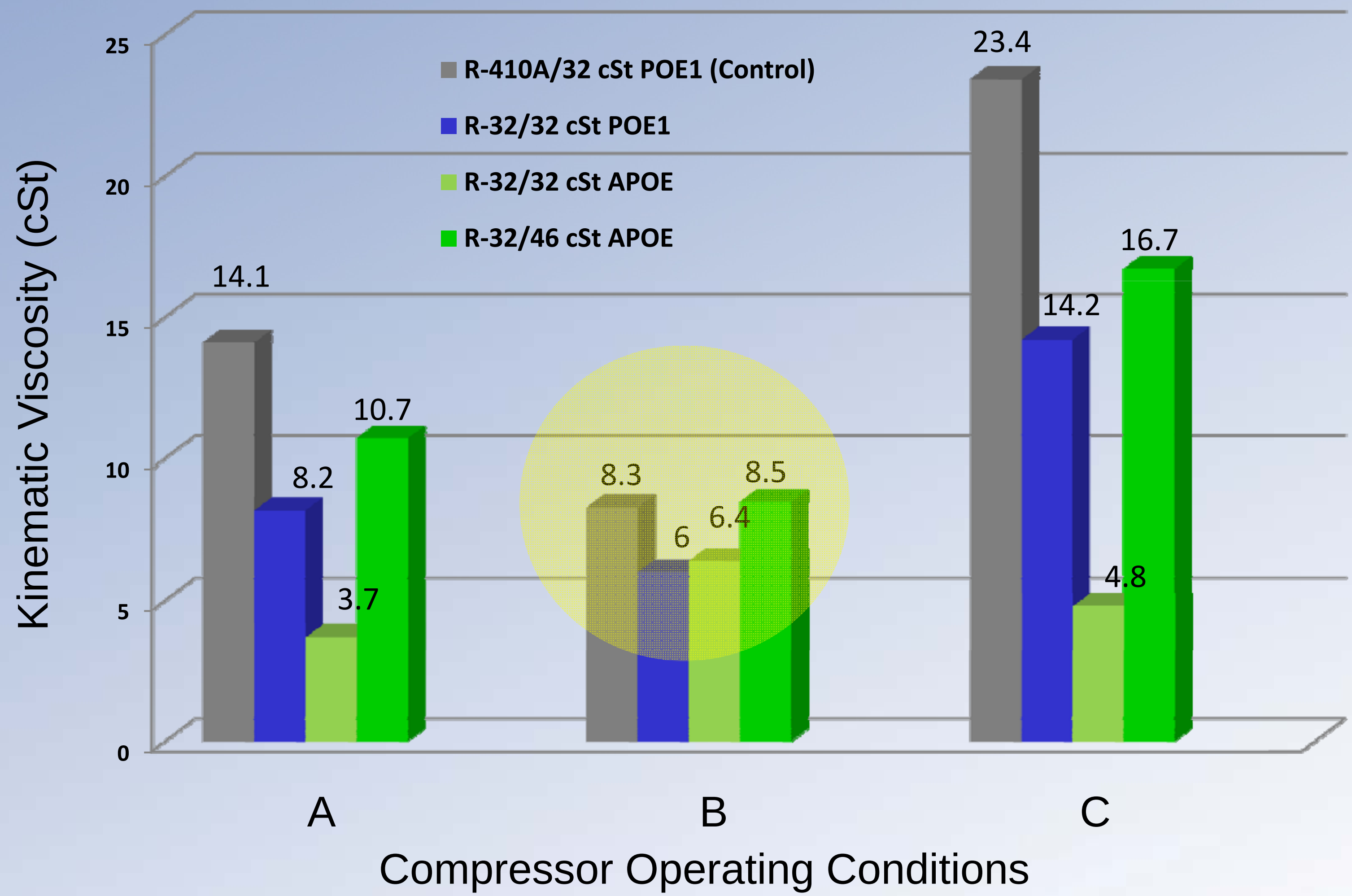
$$\begin{aligned} Log_e\left(Log_e\left(\mu + 0.7 + e^{-\mu} K_0\left(\mu + 1.244068\right)\right)\right) &= a_1 + a_2 Log_e(T) + a_3 Log_e^2(T) \\ &+ \omega\left(a_4 + a_5 Log_e(T) + a_6 Log_e^2(T)\right) \\ &+ \omega^2\left(a_7 + a_8 Log_e(T) + a_9 Log_e^2(T)\right) \end{aligned}$$

$$\begin{aligned} Log_e\left(Log_e\left(\upsilon + 0.7 + e^{-\upsilon} K_0\left(\upsilon + 1.244068\right)\right)\right) &= a_1 + a_2 Log_e(T) + a_3 Log_e^2(T) \\ &+ \omega\left(a_4 + a_5 Log_e(T) + a_6 Log_e^2(T)\right) \\ &+ \omega^2\left(a_7 + a_8 Log_e(T) + a_9 Log_e^2(T)\right) \end{aligned}$$

Constants derived from regression analysis of 30,000 measured values

Working Fluid Solution Viscosity

Blue = POE immiscible with refrigerant   Green = POE miscible with refrigerant



Note: Exact conditions for A, B and C are different for R-410A and R-32. Conditions were optimized for each refrigerant.

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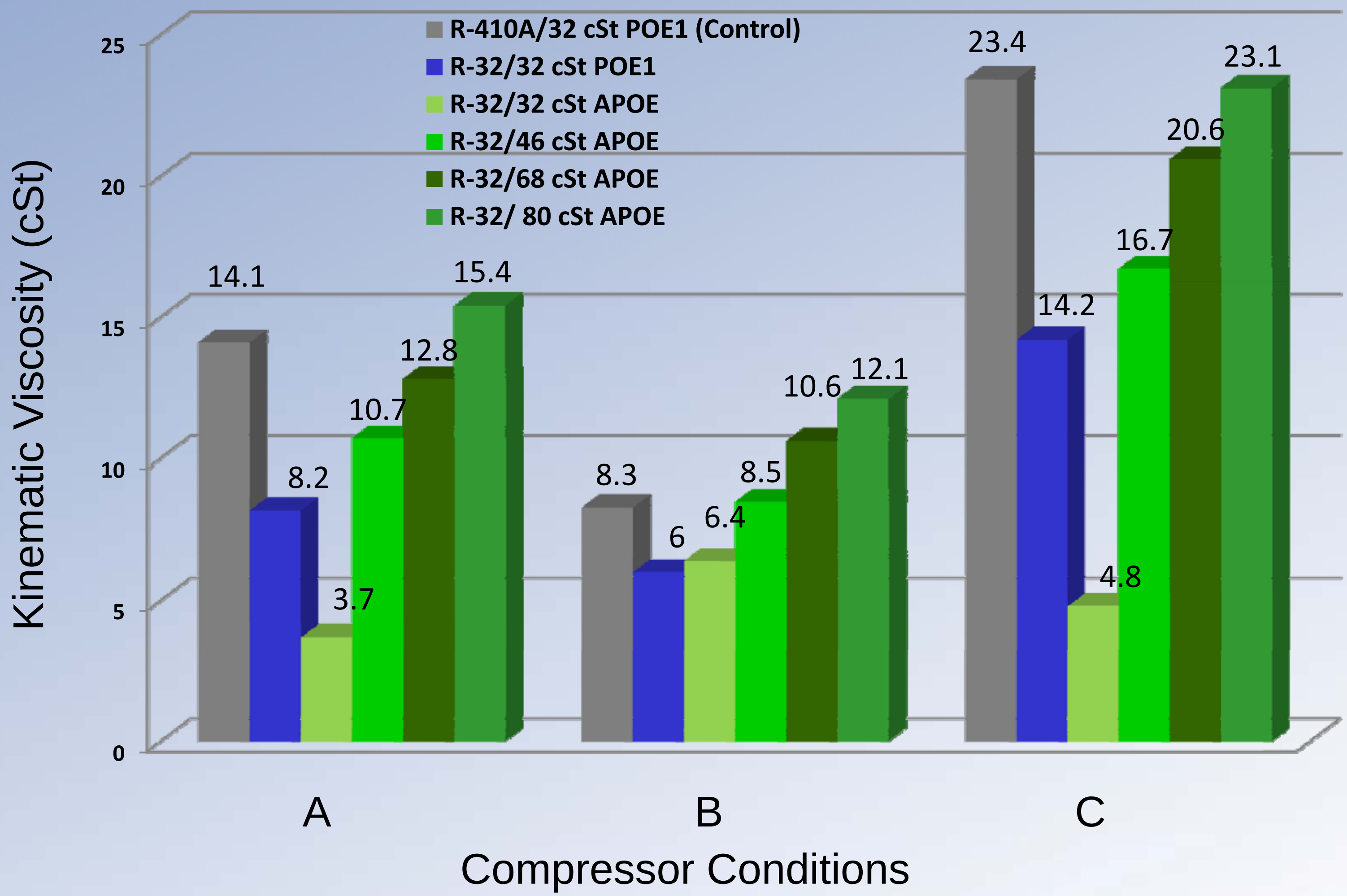

Note: Exact conditions for A, B and C are different for R-410A and R-32. Conditions were optimized for each refrigerant.

Conclusions

- Commercial synthetic lubricants used today with R-410A have significantly different compatibility with many of the alternative refrigerants being considered as low GWP replacements.
- R-32 in particular provides a significant lubrication challenge.
- It may be necessary to use higher viscosity grade lubricants which are miscible with R-32 to provide equivalent performance and system reliability.
- The impact of the optimized lubricants on system energy efficiency is under investigation.

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Questions?

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