Paper 2413

Lubricants Optimized for Use With R-32 and Related Low GWP Refrigerant Blends

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Lubricants that Improve Efficiency of Next Generation Refrigeration and AC Systems (DOE EE0003986)

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Solution Properties Of Polyol Ester Lubricants Designed For Use With R-32 And Related Low GWP Refrigerant Blends Roberto Arturo Urrego Leon, Travis L. Benanti, Edward T. Hessell

Chemtura Corporation

ID: 2502

Refrigerant and Lubricant Mass Distribution in a Convertible Split System Residential Air-Conditioner

Scott S. Wujek[1], Chad D. Bowers[1], Joshua W. Powell[1], Roberto A. Urrego[2], Edward T. Hessell[2], Travis L. Benanti[2]

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Effects of Refrigerant-Lubricant Combinations on the Energy Efficiency of a Convertible Split-System Residential Air-Conditioner, Travis L. Benanti[1], Edward T. Hessell[1], Roberto A. Urrego[1], Scott S. Wujek[2], Chad D. Bowers[2], Stefan Elbel[2]

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Considerations for Next Generation Refrigerants

- **Environmental**
  - Zero ODP
  - Low GWP (limit depends on country and application)
- **Performance**
  - Capacity, COP, Material Compatibility, LCCP
- **Safety**
  - Flammability, Toxicity, Pressure
- **Cost**
  - Ease of Manufacture, Availability
- **Value to Society in the Short Term**
  - Lower cooling and heating cost

Options for Replacement of R-22 and R-410A in AC/Heat Pump

Europe and USA

Europe (2015 F-gas)

APAC China

Refrigerant	Type	ODP	[illegible]	ASHRAE Safety Group
R-22	[illegible]	0.05	1810	A1
R-410A	HFC Blend	0	[illegible]	A1
R-32	HFC	0	[illegible]	A2L
L41b, D2Y-60, ARM-71a, DR-5, HPR1D	HFC/HFO or HFO2/HFC Blends	0	275-700	A2L*
R-1234ze R-1234yf	HFO	0	4-6	A2L
R-600a (iso-Butane)	Hydrocarbon	0	3	A3
R-290 (Propane)	Hydrocarbon	0	3	A3
R-744 (Carbon Dioxide)	Natural	0	1	A1

Refrigerant/Lubricant “Working Fluid”

Lubricant in the Refrigeration Loop

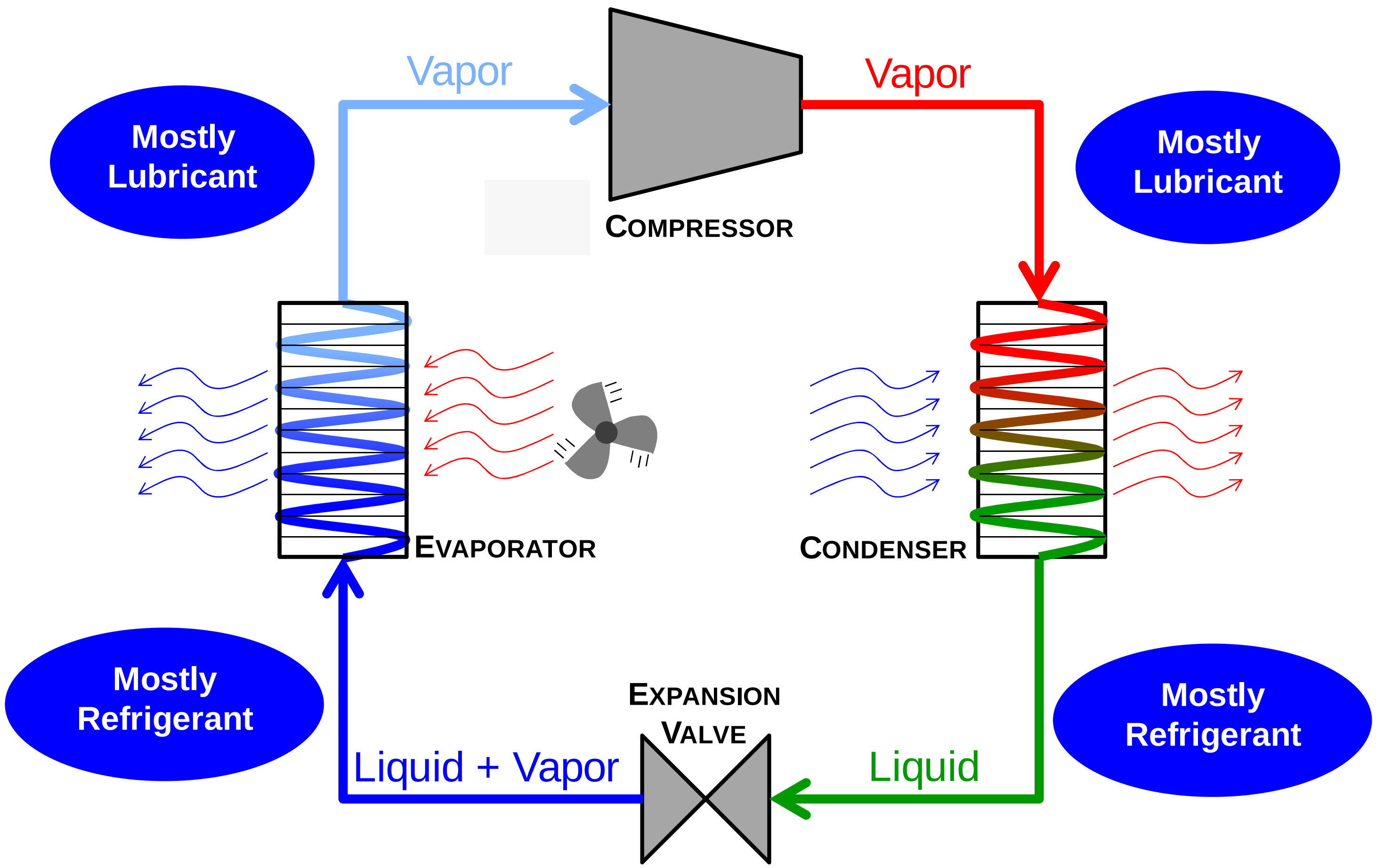
- Lubricant exits the compressor sump during compression and circulates with the refrigerant
- “Oil return” to the compressor is required to avoid frictional failure
- Anything that hinders oil return is a problem
  - System design, fouling
  - Refrigerant / lubricant mixture separation

Refrigerant in the Compressor Sump

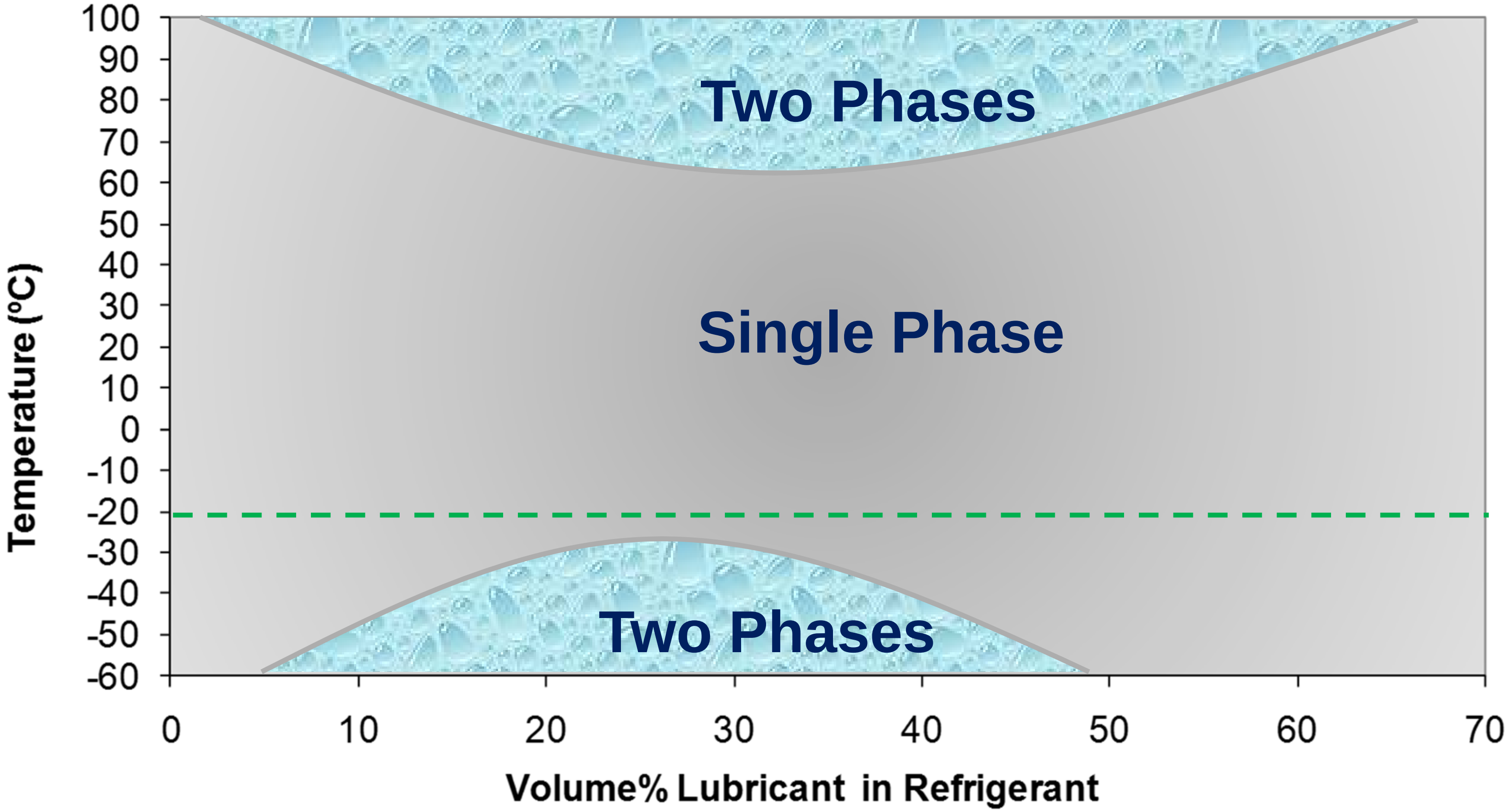
- Refrigerant dissolves in and dilutes the lubricant, which lowers its viscosity
- Viscosity of refrigerant/lubricant mixture depends on the solubility of the refrigerant in the lubricant

Can system efficiency be improved through design of lubricants optimized for next generation low GWP refrigerants?

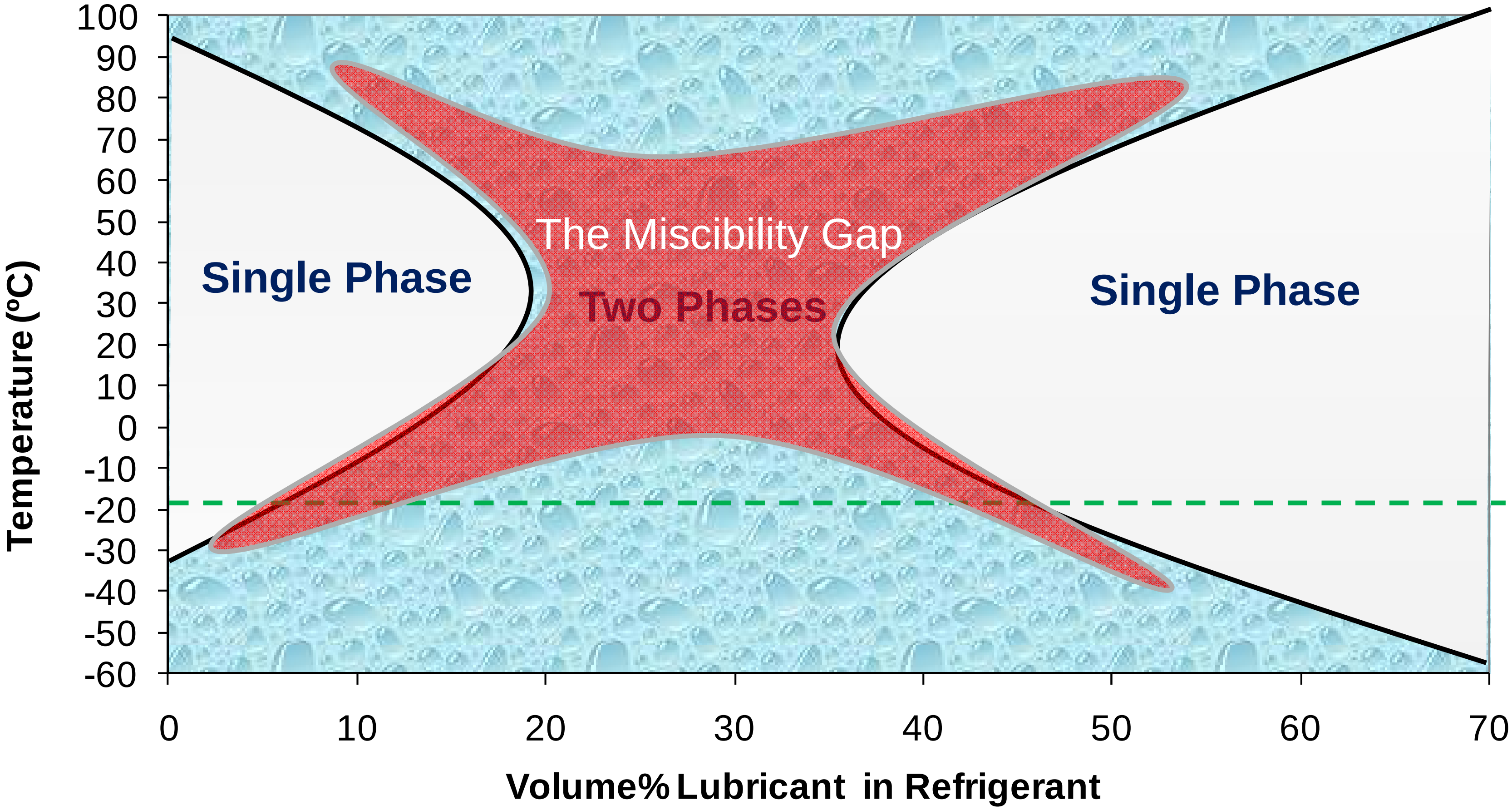
A Full Range of Working Fluid Compositions for the Liquid Phase in a Refrigeration Cycle



Miscibility Profile of a Traditional POE in R-410A



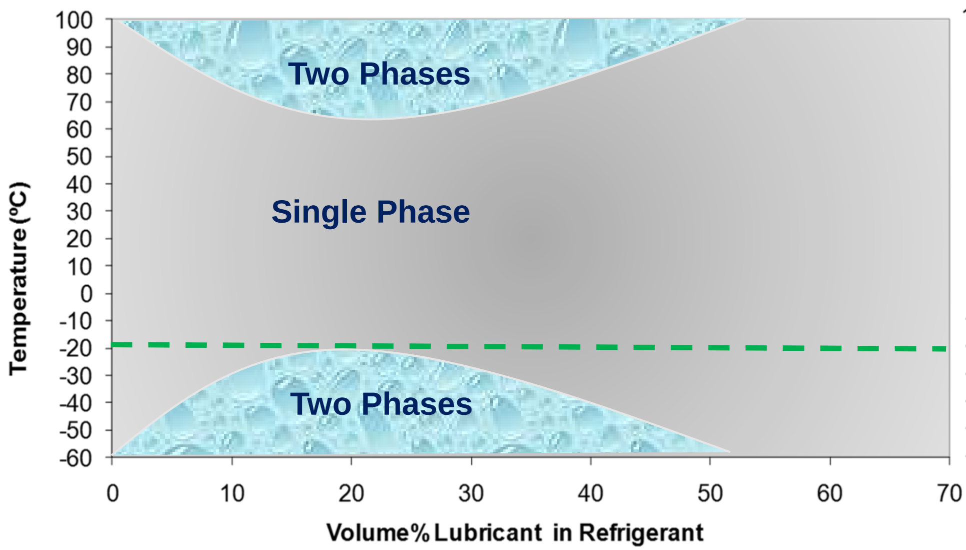
Miscibility Profile of a Traditional POE in R-32



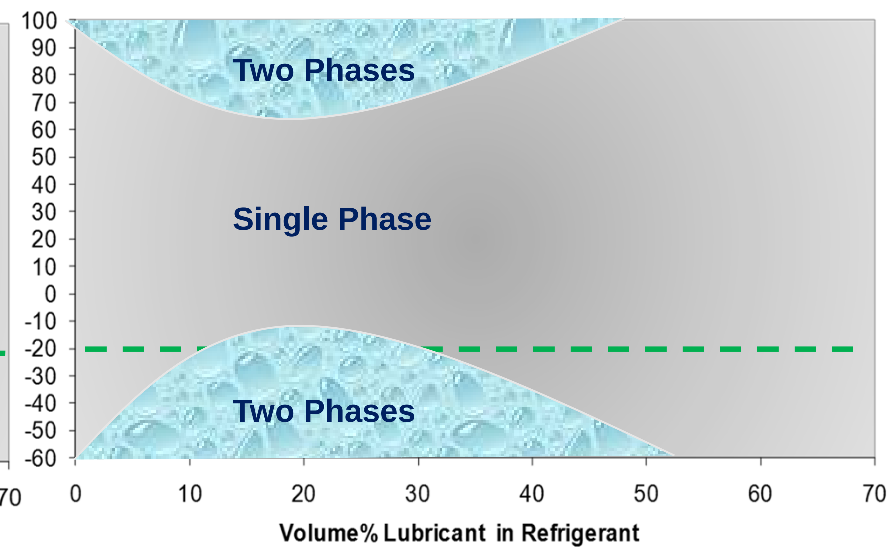
Could the "gap" result in poor oil return and/or decreased HX efficiency?

Miscibility of ISO 32 and ISO 68 POEs Optimized for R-32 Refrigerant

32 cSt POE 2



68 cSt APOE*



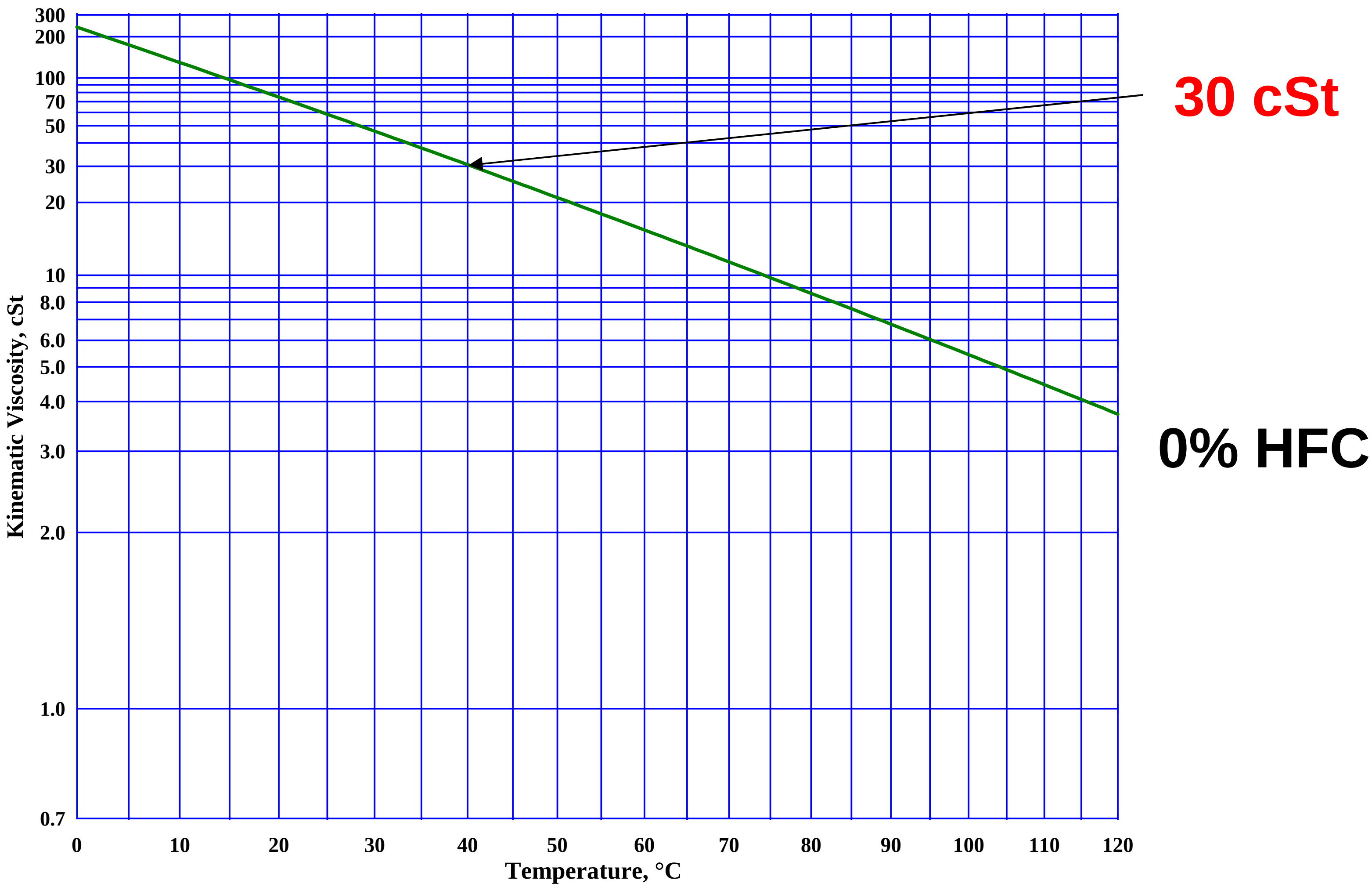
Can make POEs miscible with R-32 independent of oil viscosity

*APOE = "Advanced Polyol Ester"

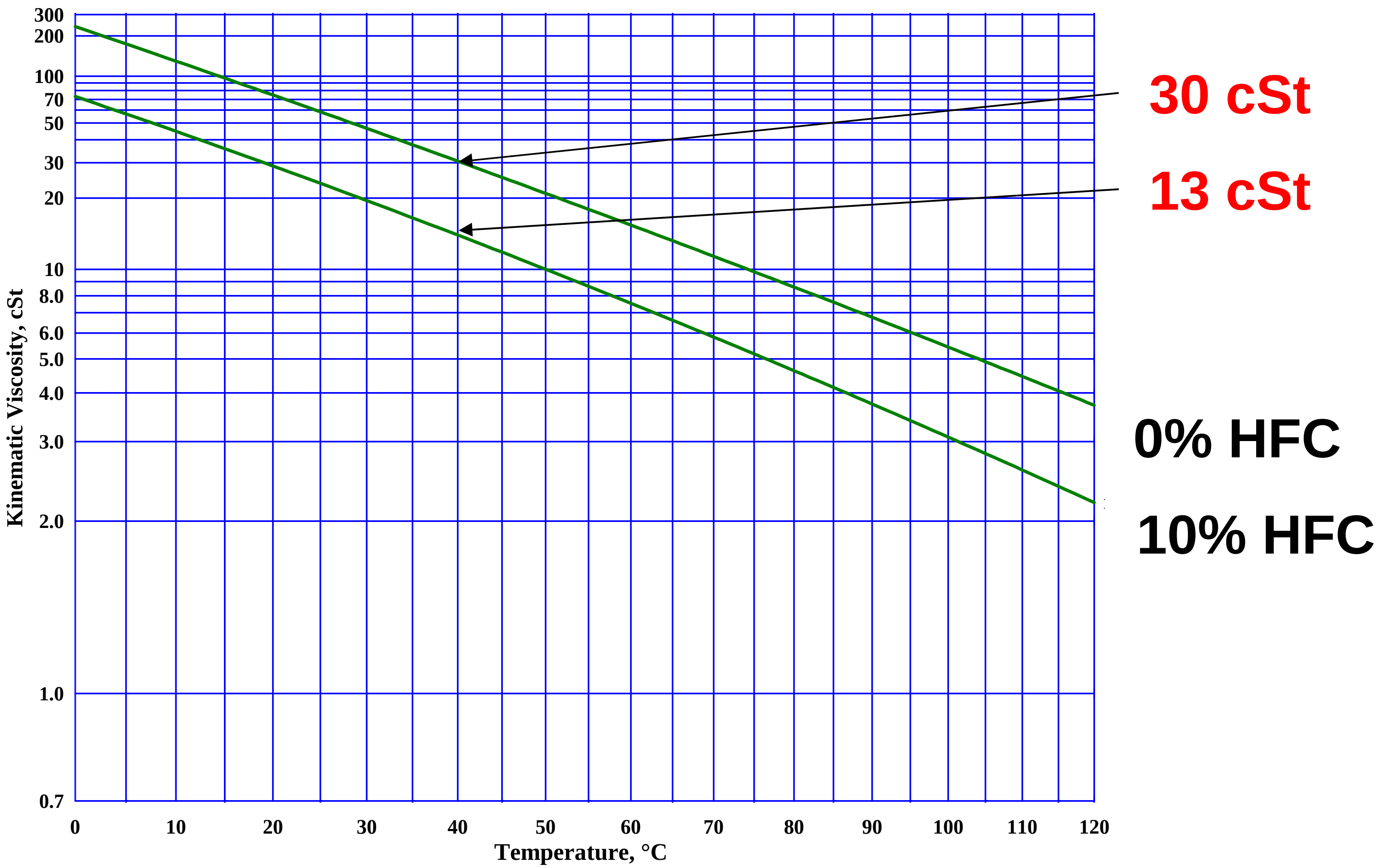
POE Property Comparisons

Lubricant	32 cSt POE 1	32 cSt POE 2	68 cSt POE 1	68 cSt APOE	80 cSt APOE
KV @ 40 °C	31	31	72	64.1	80.3
Pour Point (°C)	-60	-54	-44	-45	-42
Critical Solution Temperature in R-32					
10 vol% Oil in Refrigerant	+2	-32	+10	-17	-18
20 vol% Oil in Refrigerant	+20	-24	Not Miscible	-13	-5
30 vol% Oil in Refrigerant	Not Miscible	-20	Not Miscible	-15	-6
60 vol% Oil in Refrigerant	-25	-63	-6	-46	-45

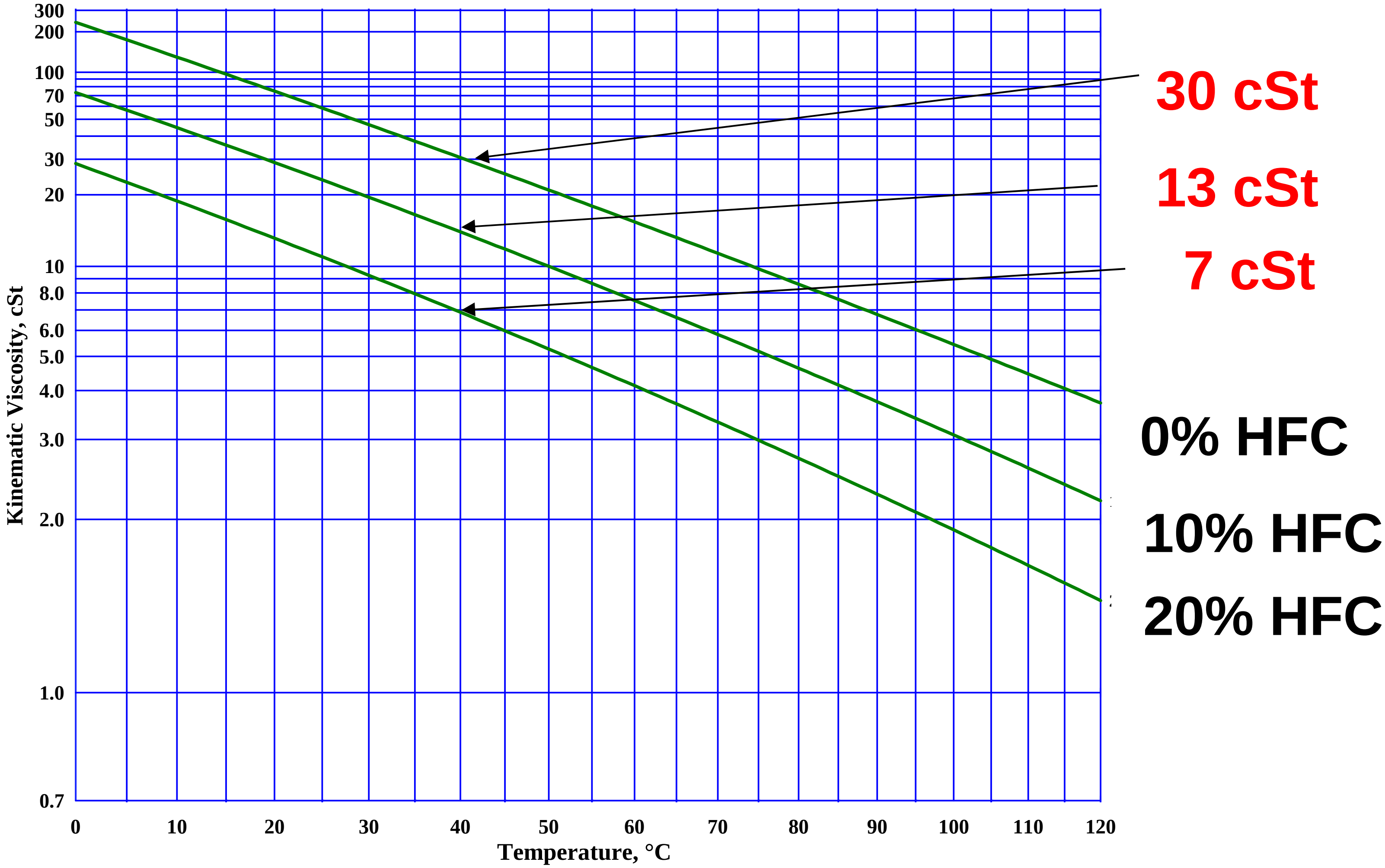
Impact of Dissolved Refrigerant on the Viscosity of the Lubricant



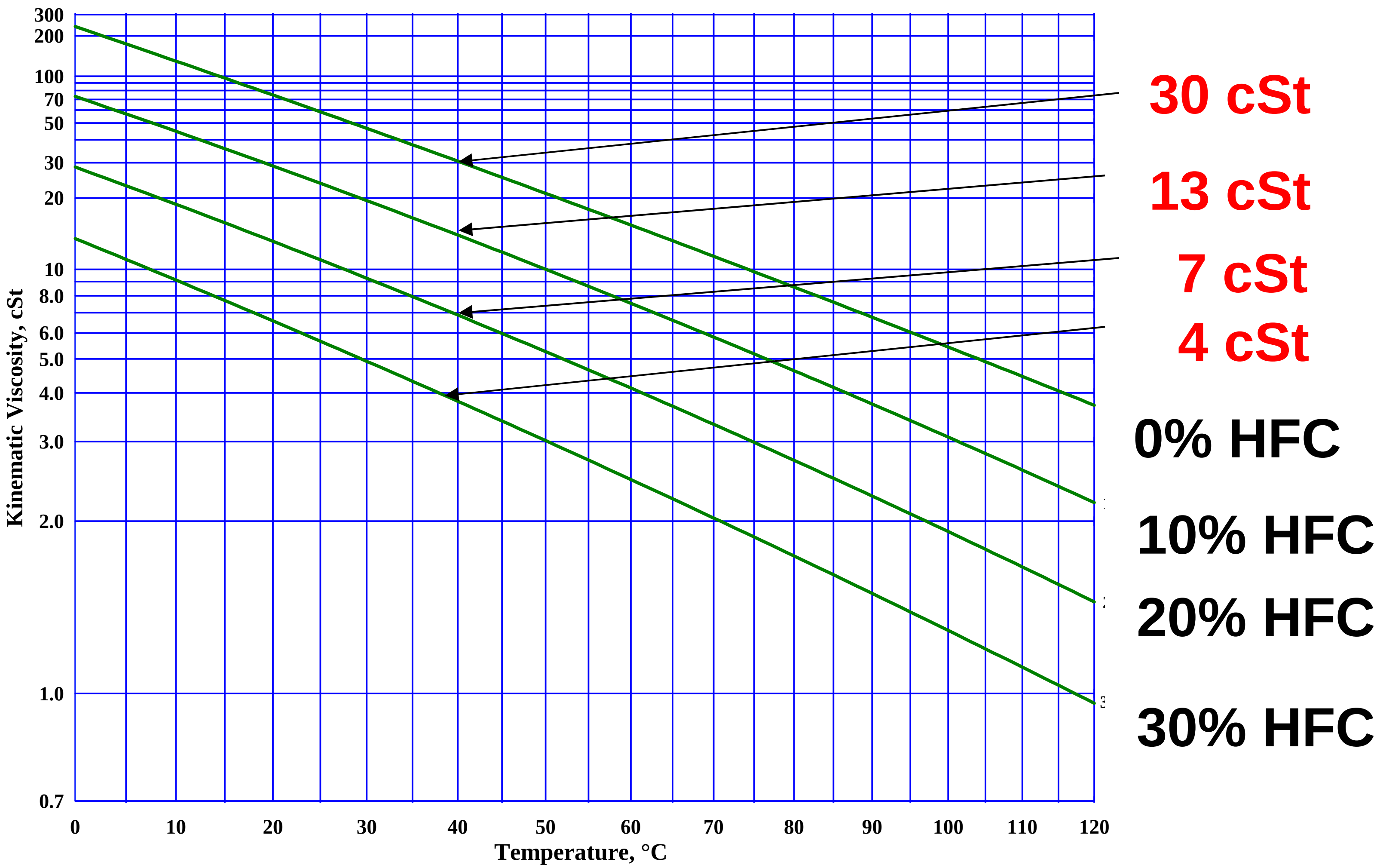
Impact of Dissolved Refrigerant on the Viscosity of the Lubricant



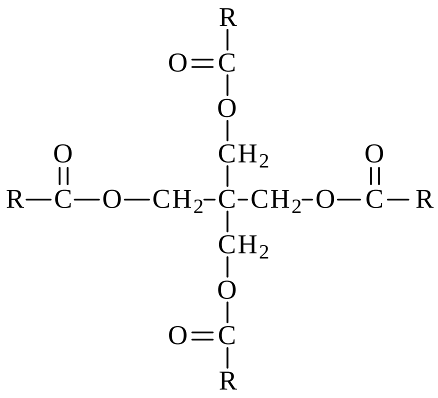
Impact of Dissolved Refrigerant on the Viscosity of the Lubricant



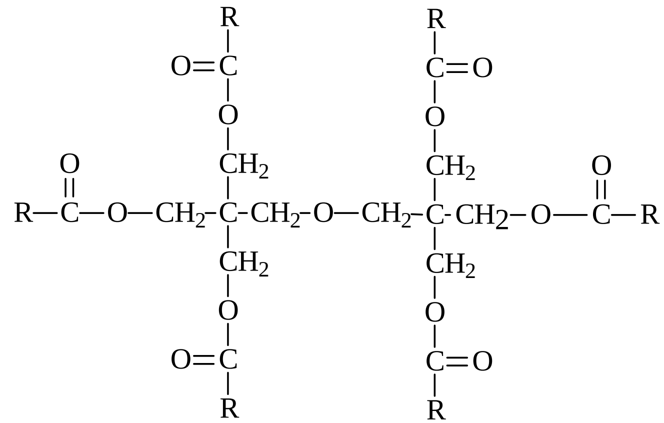
Impact of Dissolved Refrigerant on the Viscosity of the Lubricant



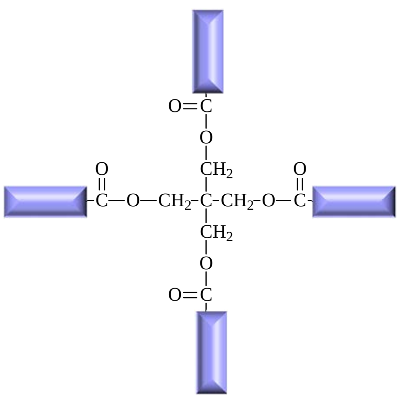
A Bit of Chemistry
Polyol Ester Chemical Structures



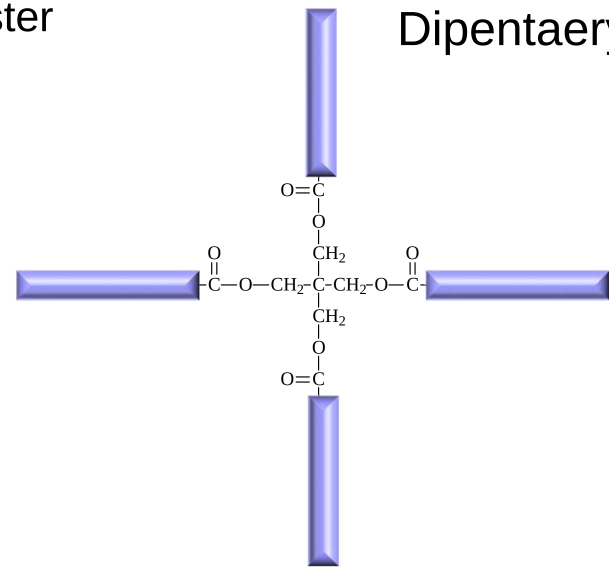
Pentaerythritol Ester



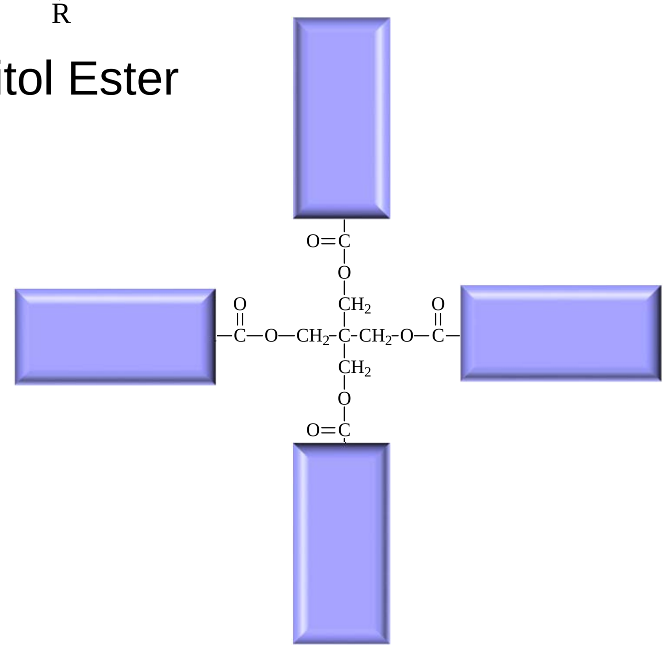
Dipentaerythritol Ester



Short Chain Linear

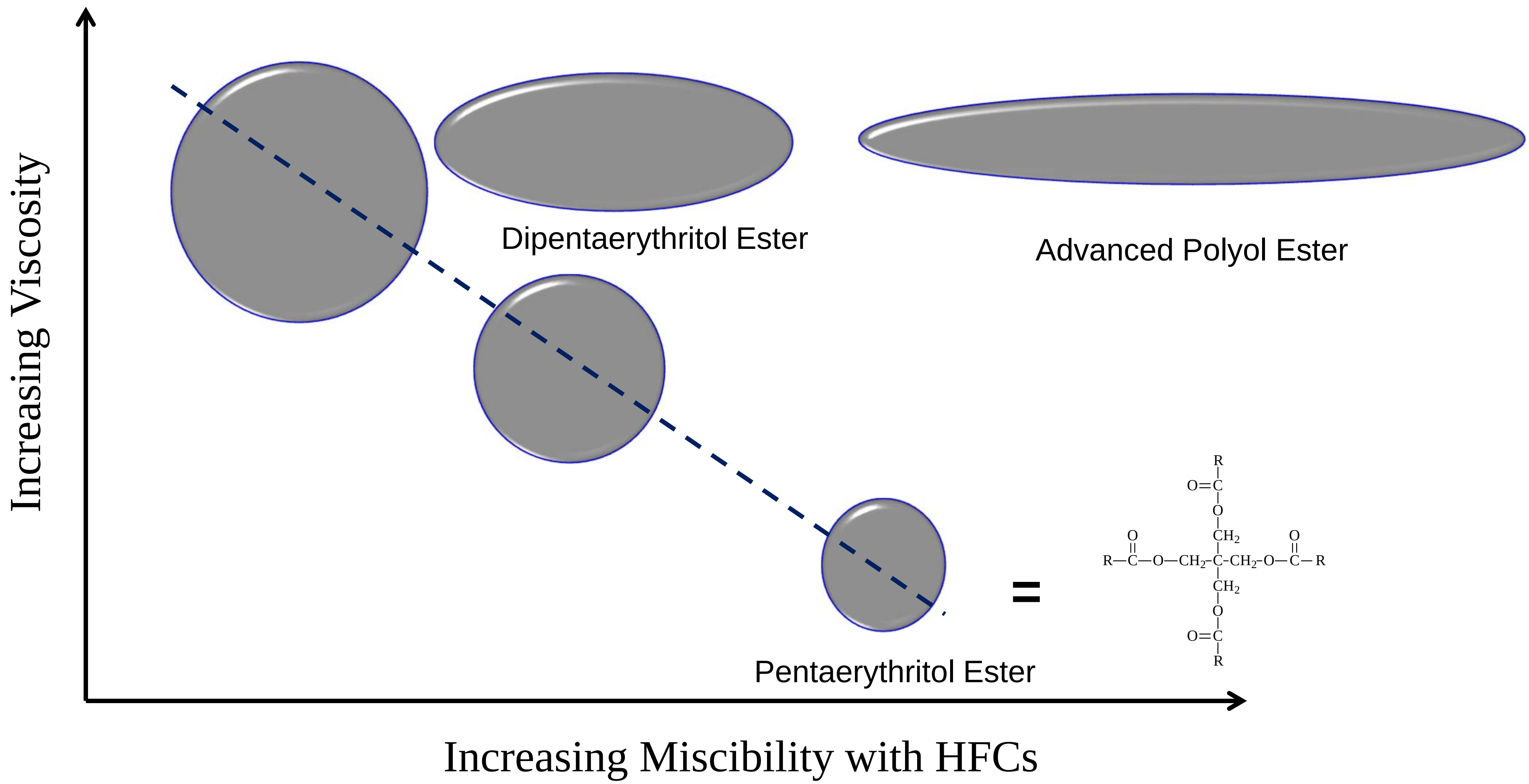


Long Chain Linear

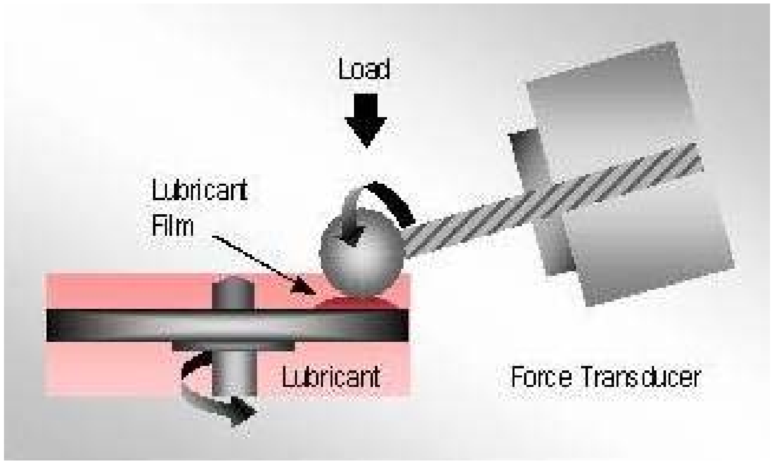


Long Chain Branched

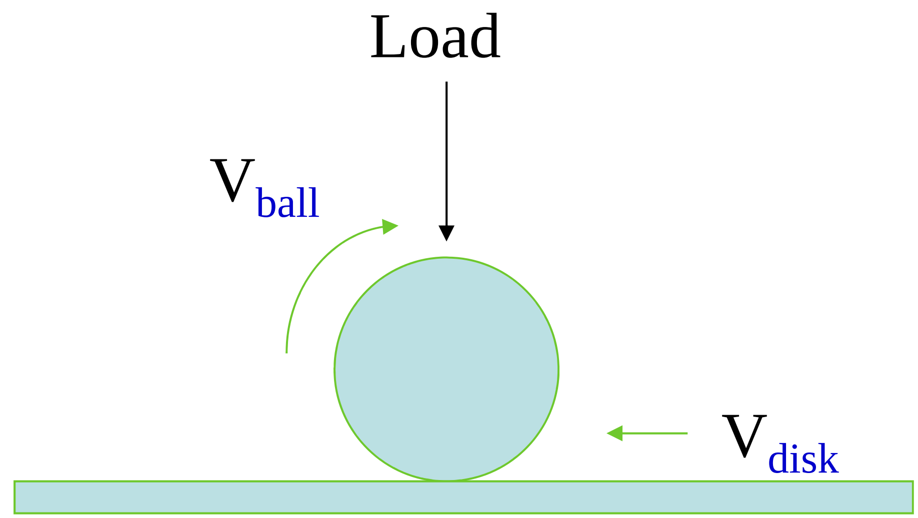
Relationship of Chemical Structure to Lubricant Viscosity and Refrigerant Miscibility



Measuring the Lubricity Performance of Lubricants with the Mini-Traction Machine (MTM)



Drive and Measurement Mechanism

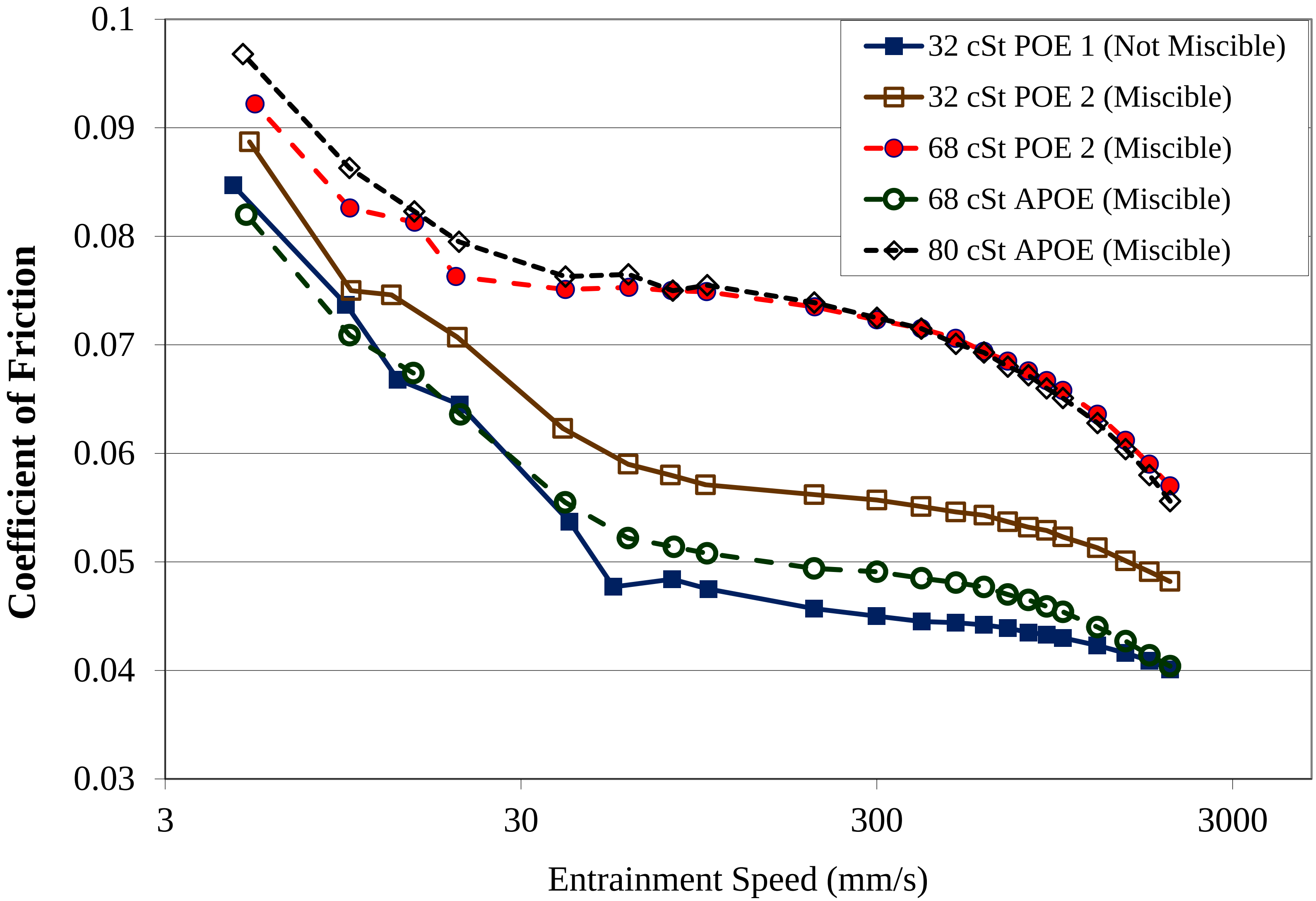


Contact Geometry

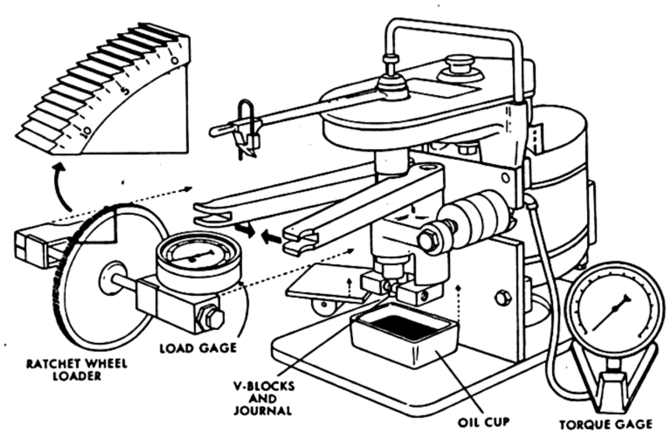
$$\text{Mean Entrainment Speed} = \frac{(V_{disk} + V_{ball})}{2}$$

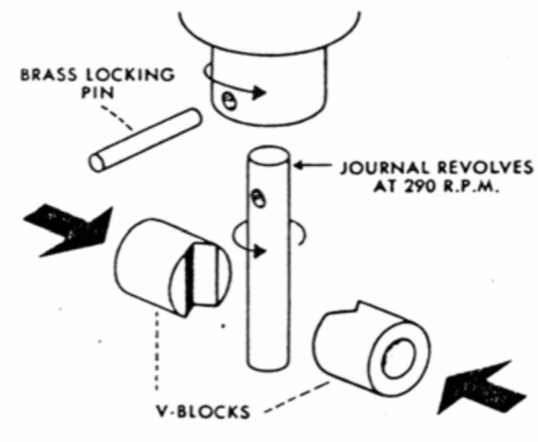
$$\text{Slide Roll Ratio (SRR)} = \frac{2(V_{disk} - V_{ball})}{(V_{disk} + V_{ball})}$$

Lubricity Performance
70 N Load, Fixed SRR = 50%



Falex Pin and Vee Block Test
ASTM D 3233, Method A





POE Lubricant ID	ISO Viscosity Grade and Description	ASTM D 3233 Failure Load (Method A), (lbs. force at pin failure)
POEs Designed for R-410A		
32 cSt POE 1	ISO 32 PE Ester	950
68 cSt POE 1	ISO 68 PE/DiPE Ester	875
POEs Designed for R-32		
32 cSt POE 2	ISO 32 PE Ester	750
68 cSt POE 2	ISO 68 PE/DiPE Ester	700
32 cSt APOE	ISO 32 Advanced PE Ester	>1000
68 cSt APOE	ISO 68 Advanced PE Ester	>1000
80 cSt APOE	ISO 80 Advanced PE Ester	875

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 but is a leading low GWP candidate for AC/HP because of low cost and comparable LCCP vs. R-410A.

- It is possible to synthesize polyol esters that have a combination of high viscosity, acceptable miscibility in R-32 along with high load carrying and lubricity performance.

- It has been demonstrated that properly optimized lubricant/refrigerant pairs can improve energy efficiency in next generation environmentally sustainable AC systems.

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QUESTIONS?

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