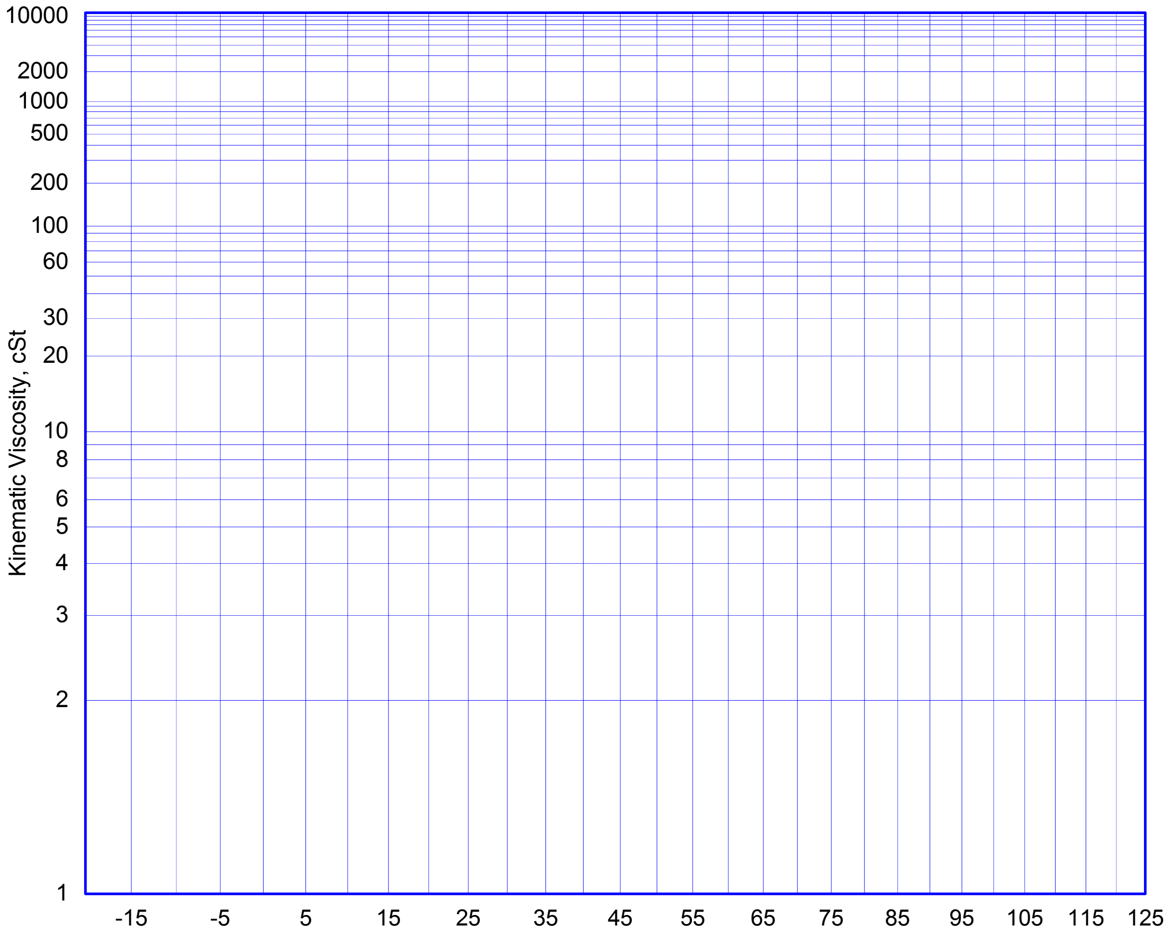
Solubility, Miscibility, and Liquid Viscosity of Lubricants with CO_2 and Propane

Chris Seeton

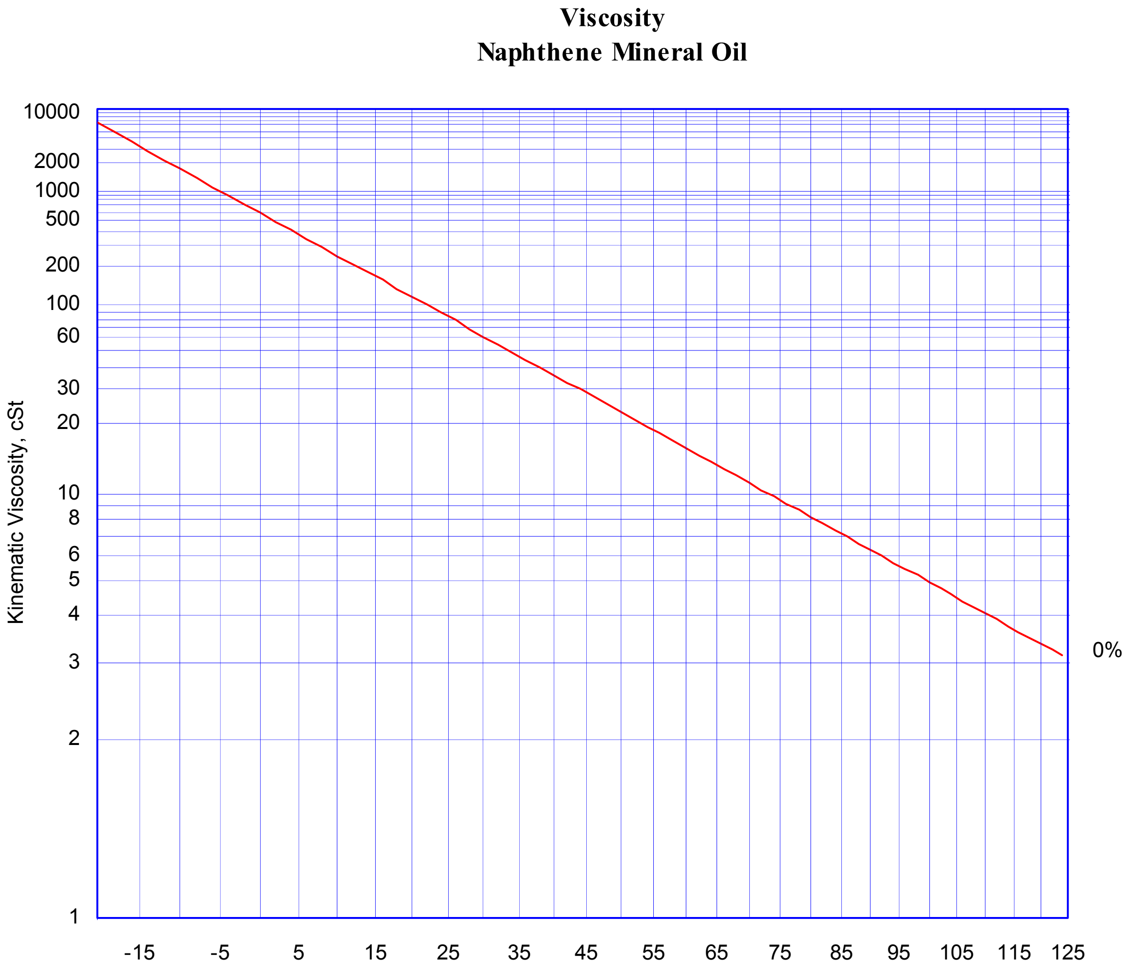
Seeton C&P

University of Illinois at Urbana-Champaign

Viscosity – Temperature Chart
ASTM D 341-93 (1998)



Viscosity – Temperature Chart
ASTM D 341-93 (1998)



Viscosity – Temperature Chart
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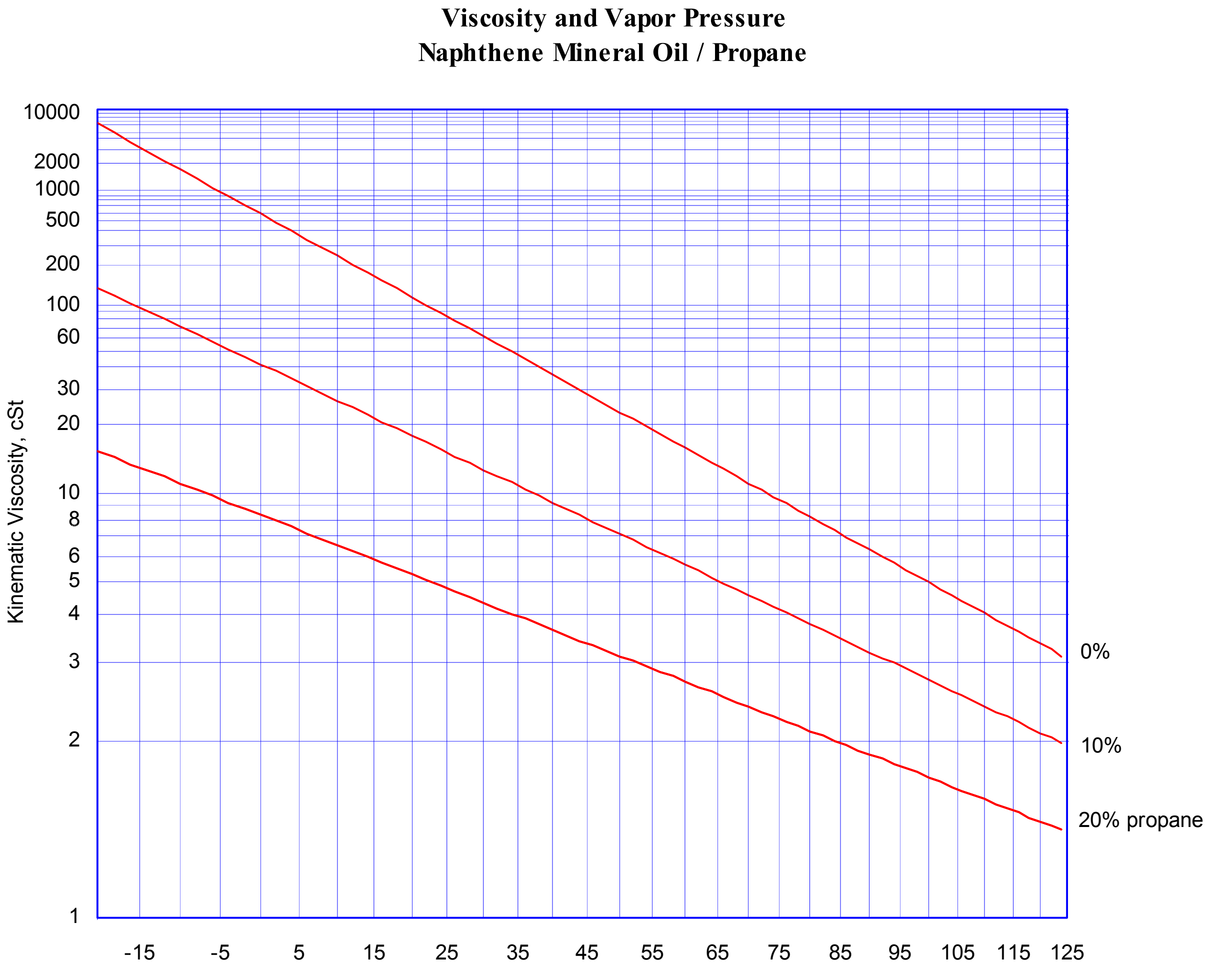
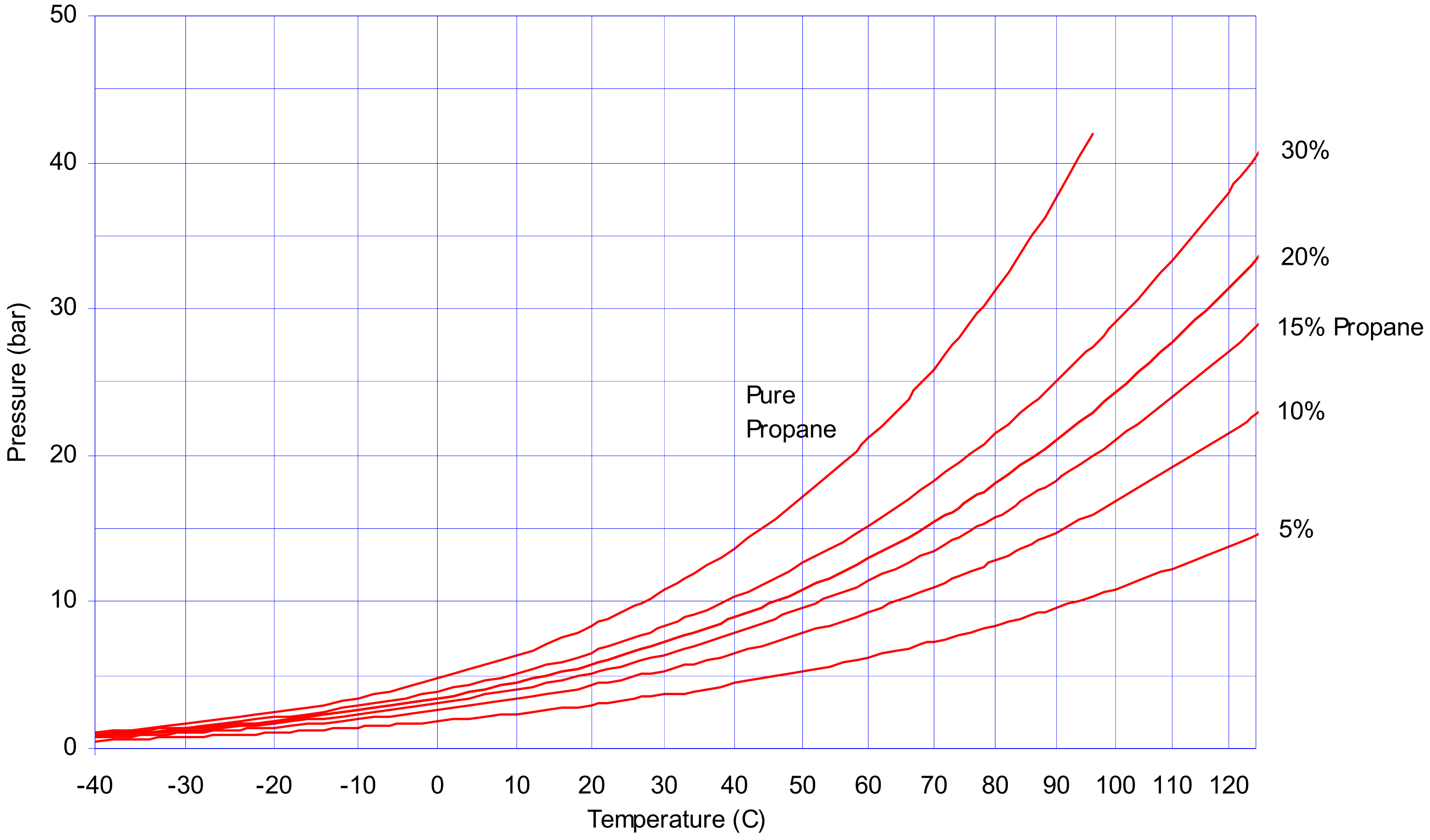
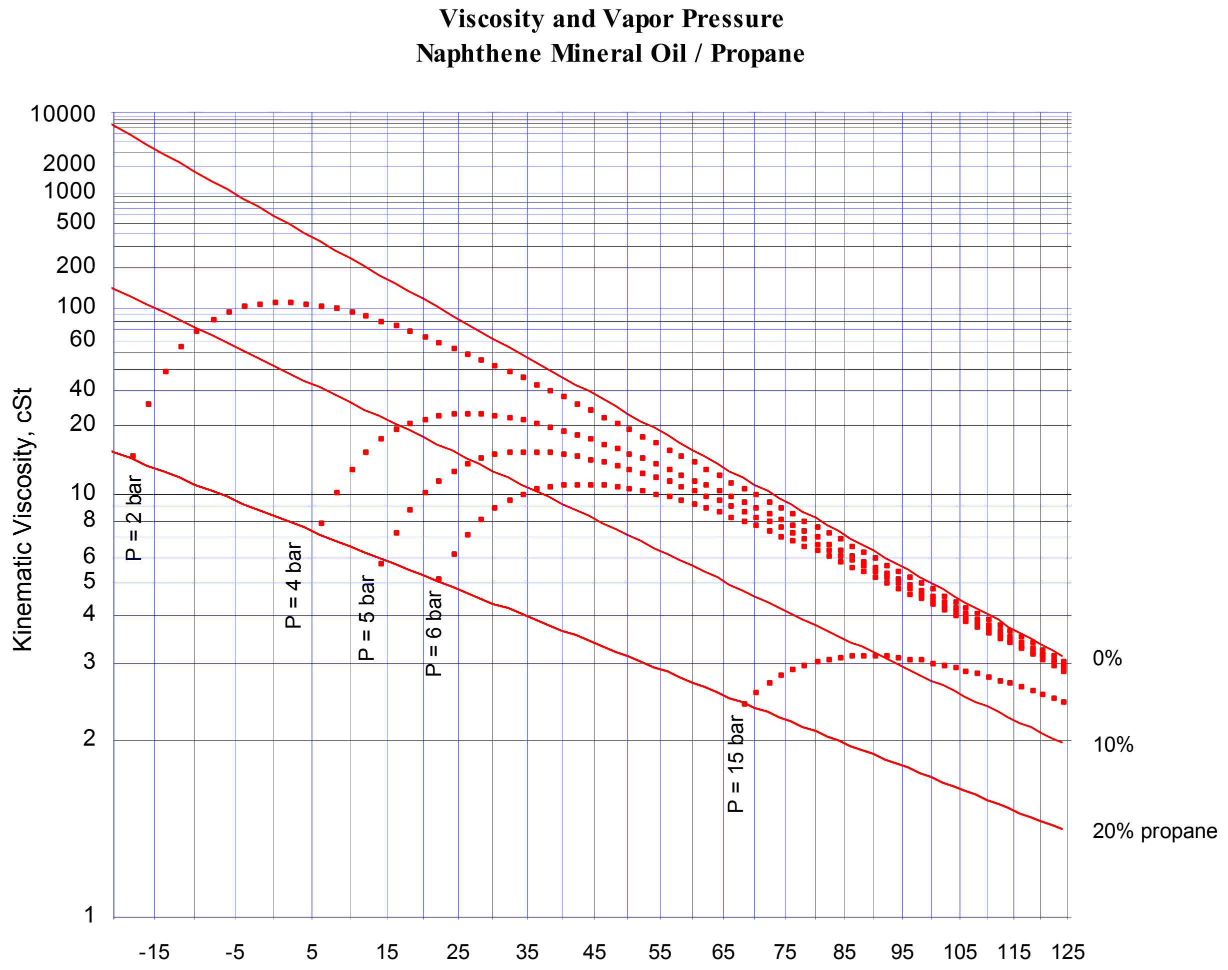


Solubility
Naphthenic Mineral Oil 32 / Propane

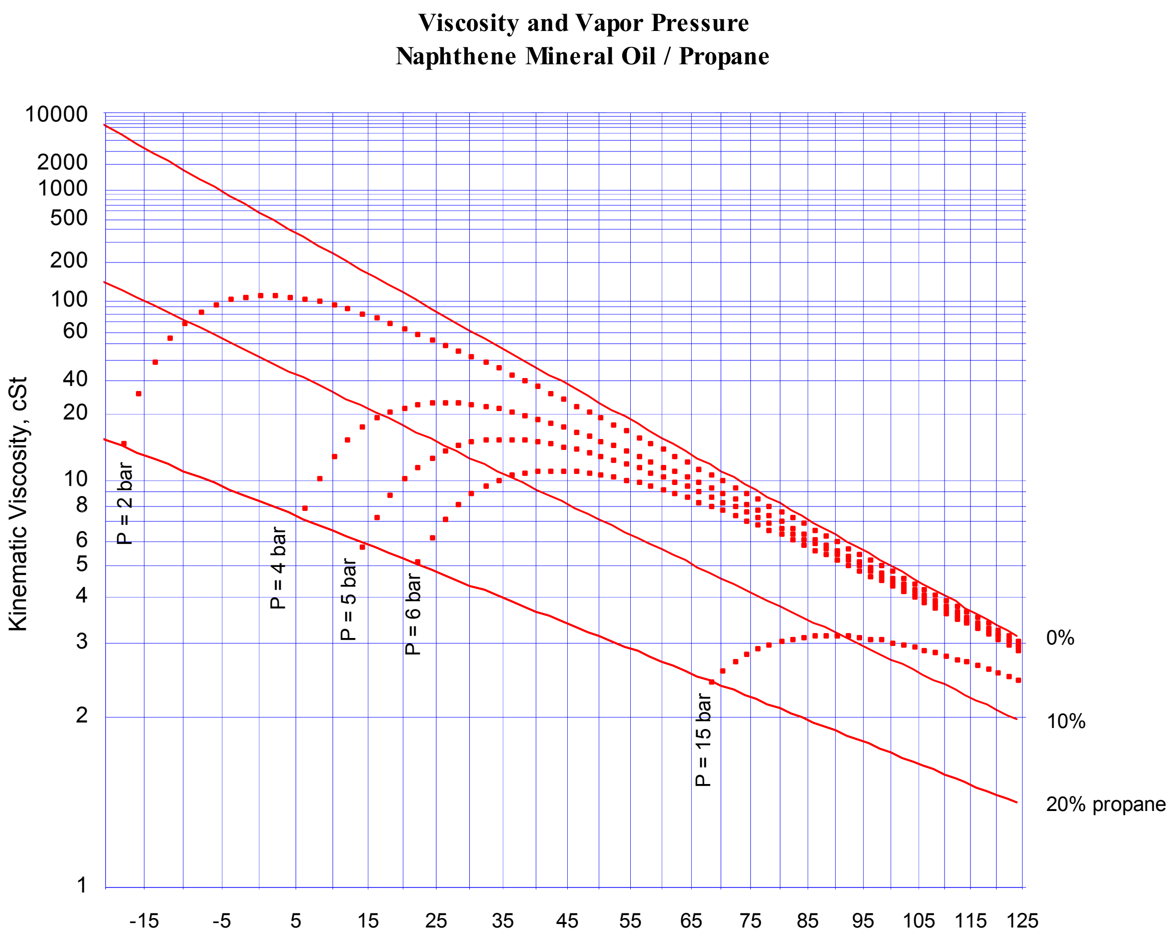


Viscosity – Temperature Chart

Daniel Chart



Naphthenic Mineral Oil 32 / Propane
Daniel Chart

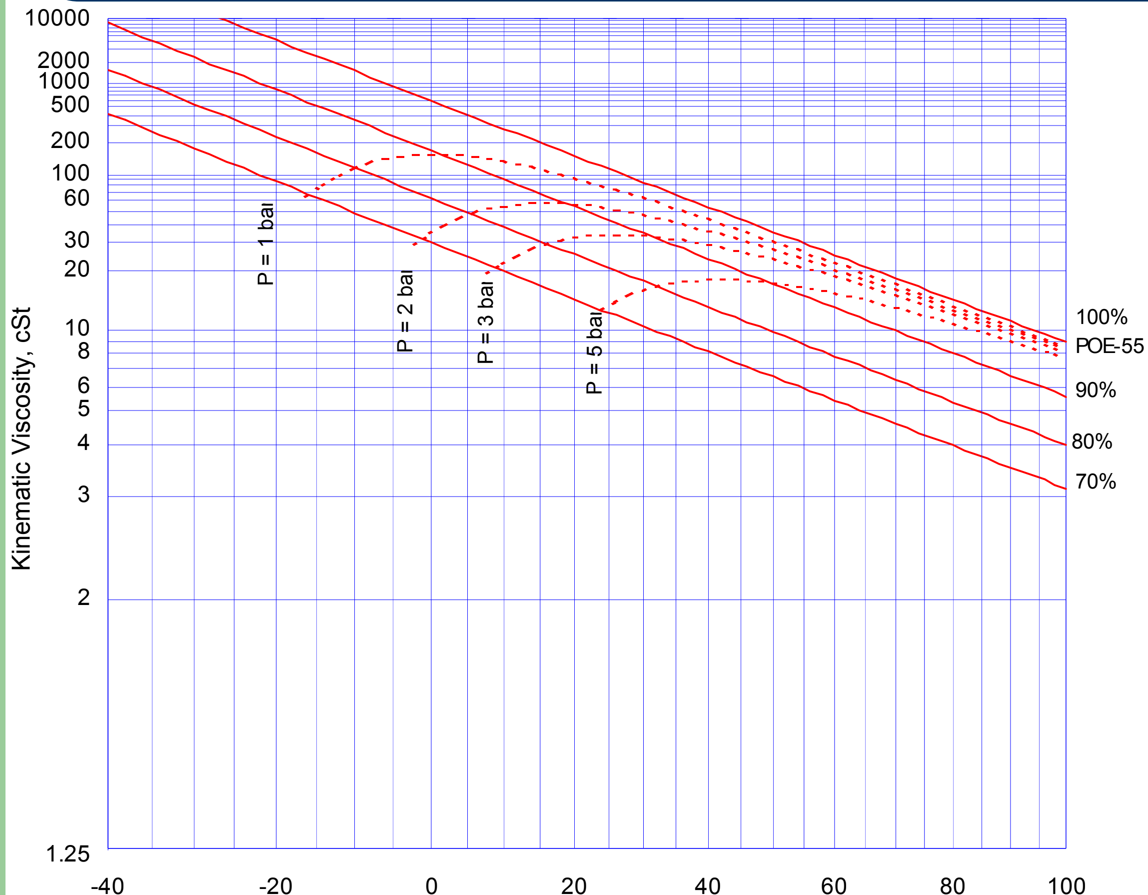


Assume:
Evaporator = -6°C
Suction Pressure = 4 bar
6°C Superheat
10°C Suction Line HX
20°C Rise in Compressor

Bearing Lubrication Temp.
30°C

Pure Lubricant Viscosity
62 cSt
Mixture Viscosity
22 cSt

POE-55 / R-134a
Daniel Chart



Assume:

Evaporator = -6°C

Suction Pressure = 2.3 bar

6°C Superheat

10°C Suction Line HX

20°C Rise in Compressor

Bearing Lubrication Temp.

30°C

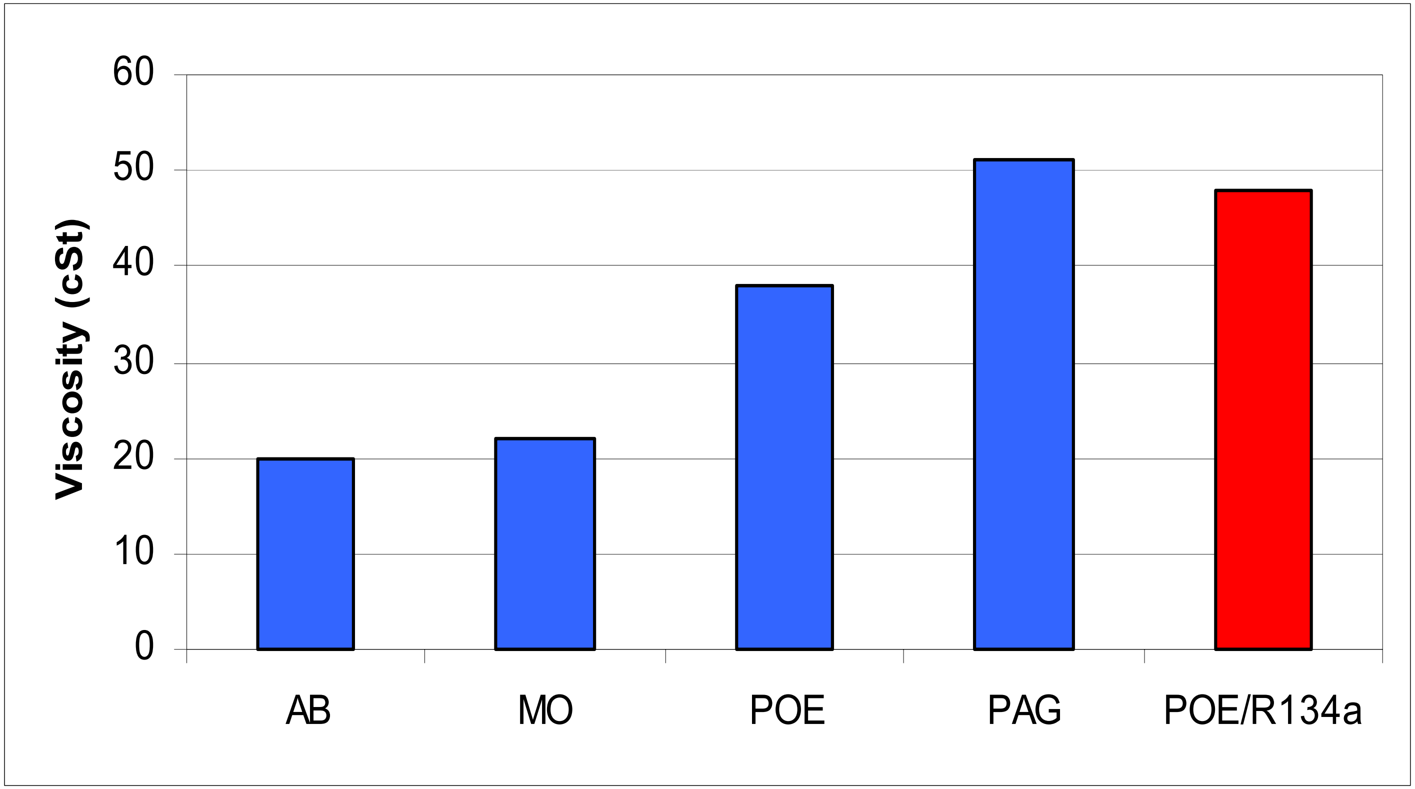
Pure Lubricant Viscosity

85 cSt

Mixture Viscosity

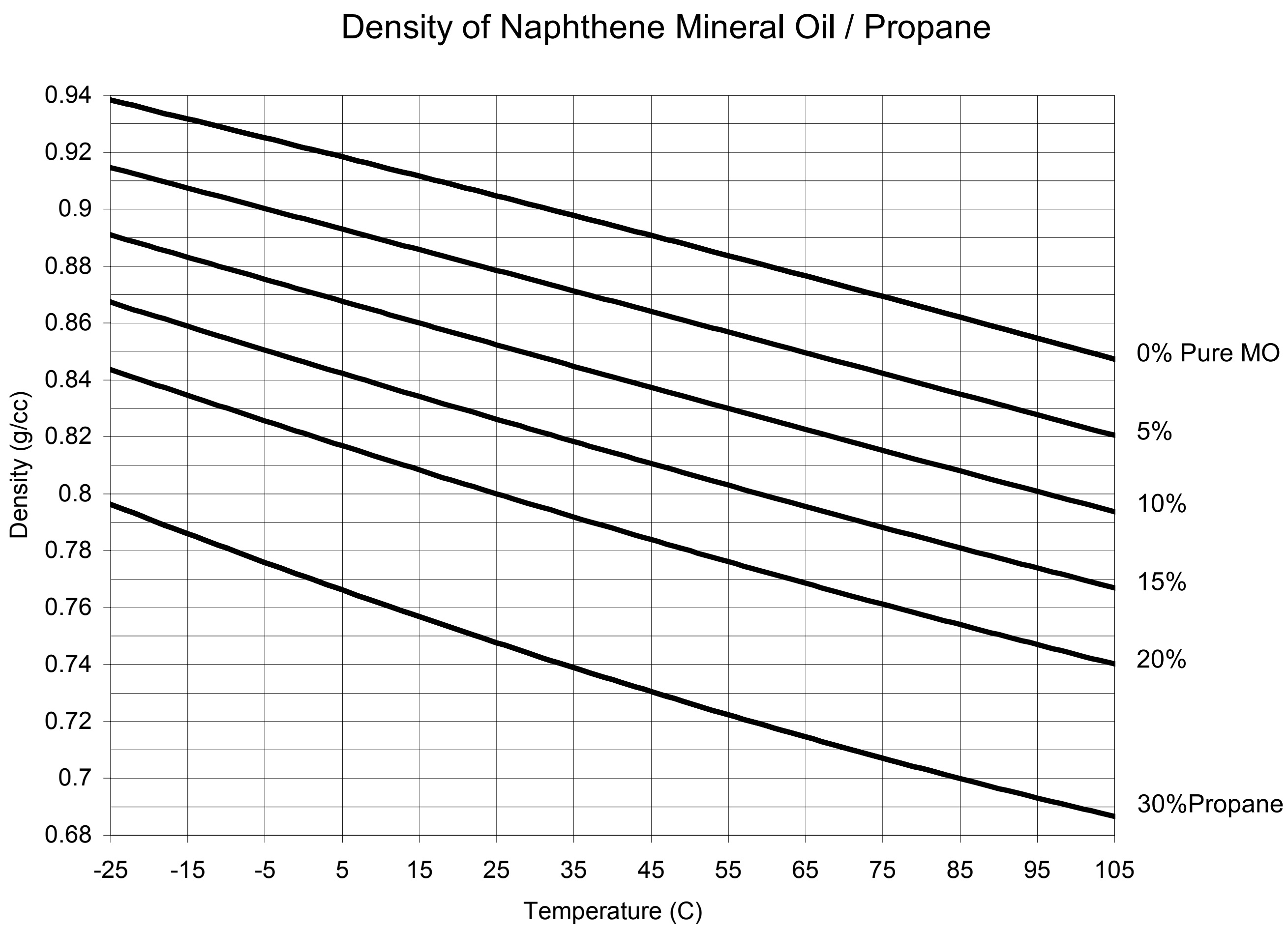
48 cSt

Viscosity Comparison
ISO 32 Lubricants with Propane



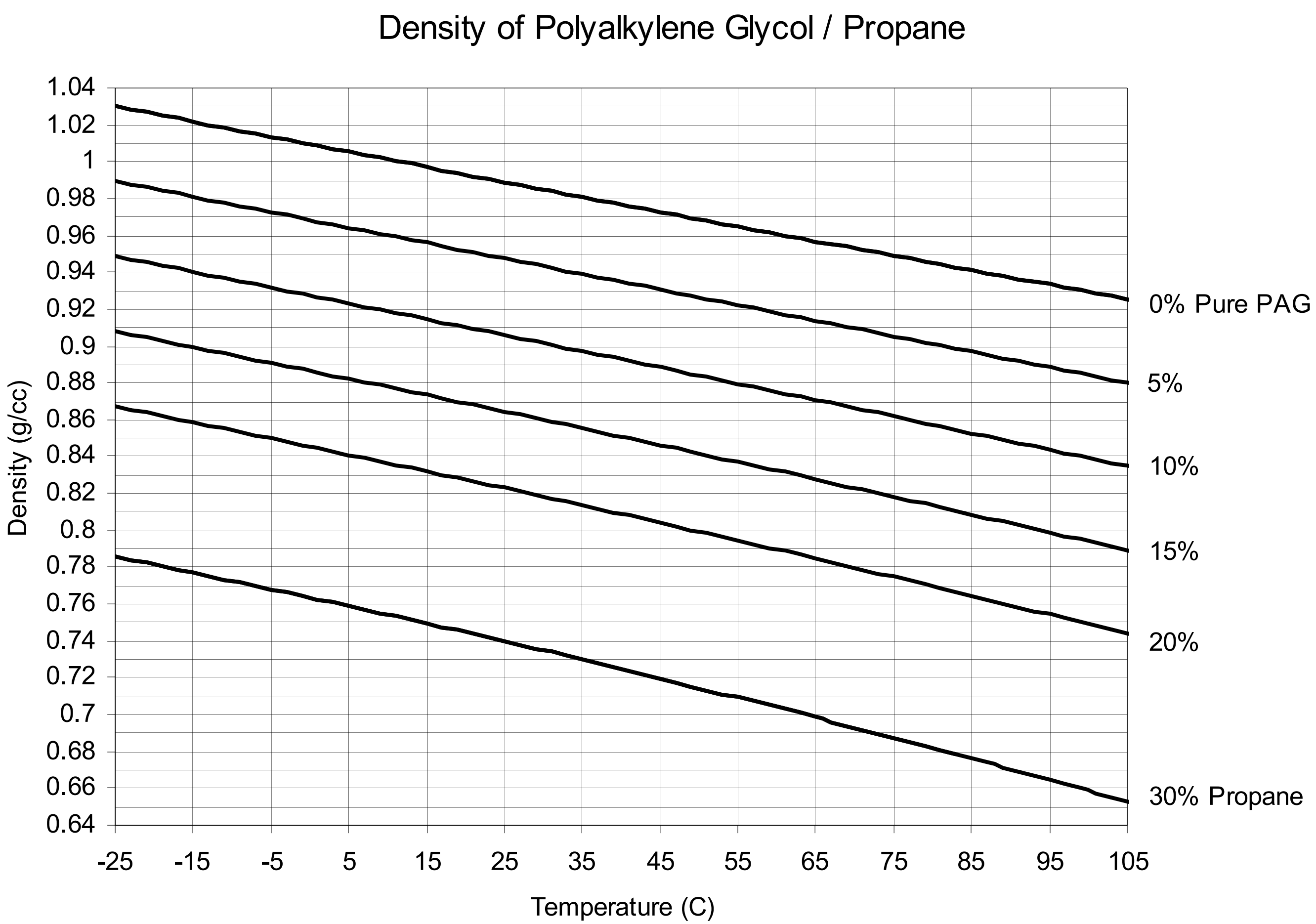
- Test Condition: -6°C Evaporating, 6°C Superheat, 10°C Suction Line HX, 20°C Compressor Heating

Density
Naphthenic Mineral Oil 32 / Propane



Density

Polyalkylene Glycol 46 / Propane

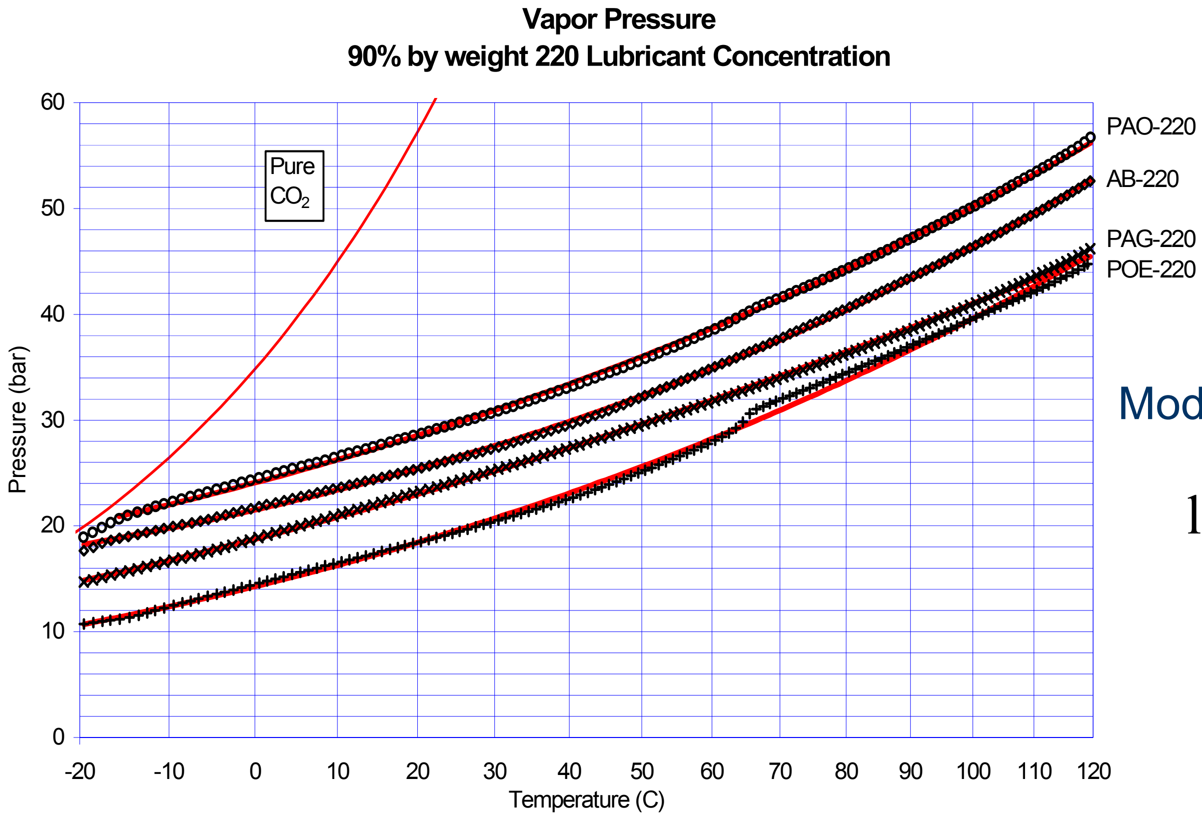


Propane Miscibility

- POE, AB, and MO showed excellent solubility with propane
- PAG showed a saturated pressure close to pure propane for 30% compositions
  - Could be a sign of possible immiscibility
  - More testing is necessary

Solubility

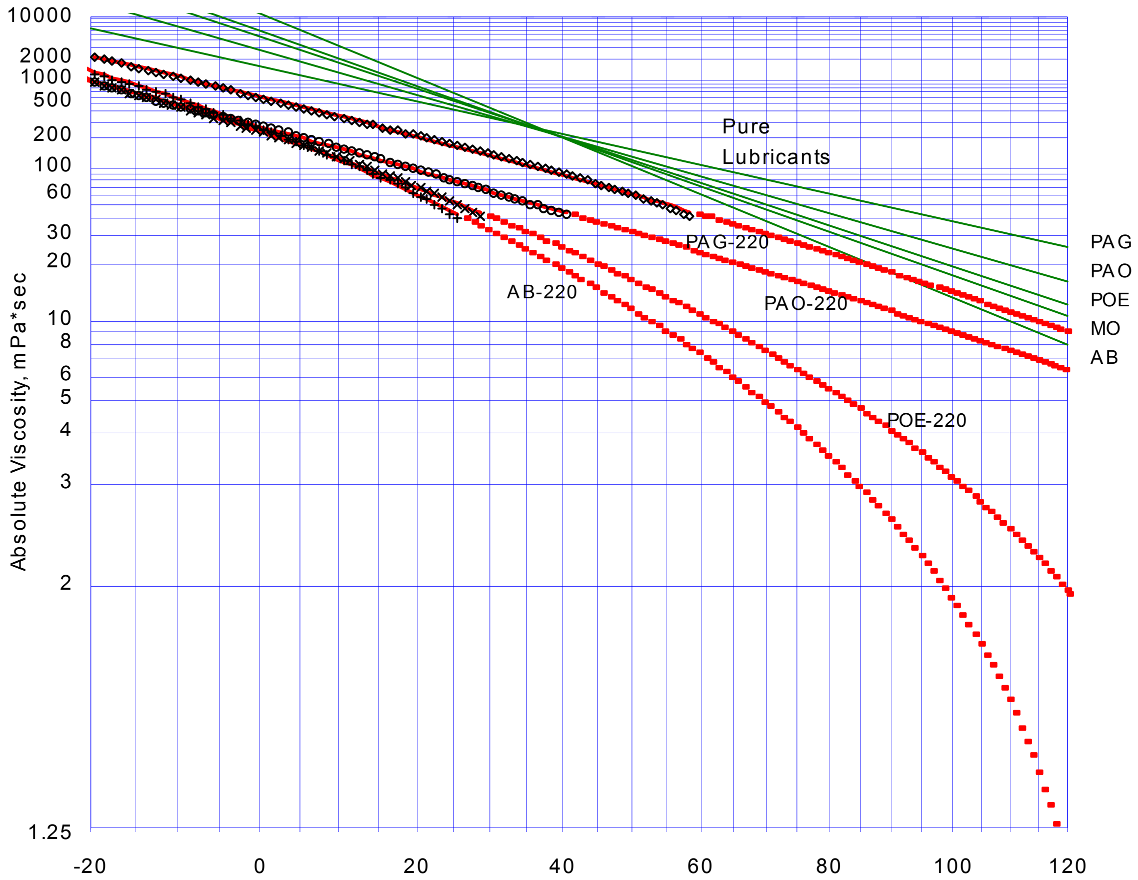
PAO > AB > PAG > POE



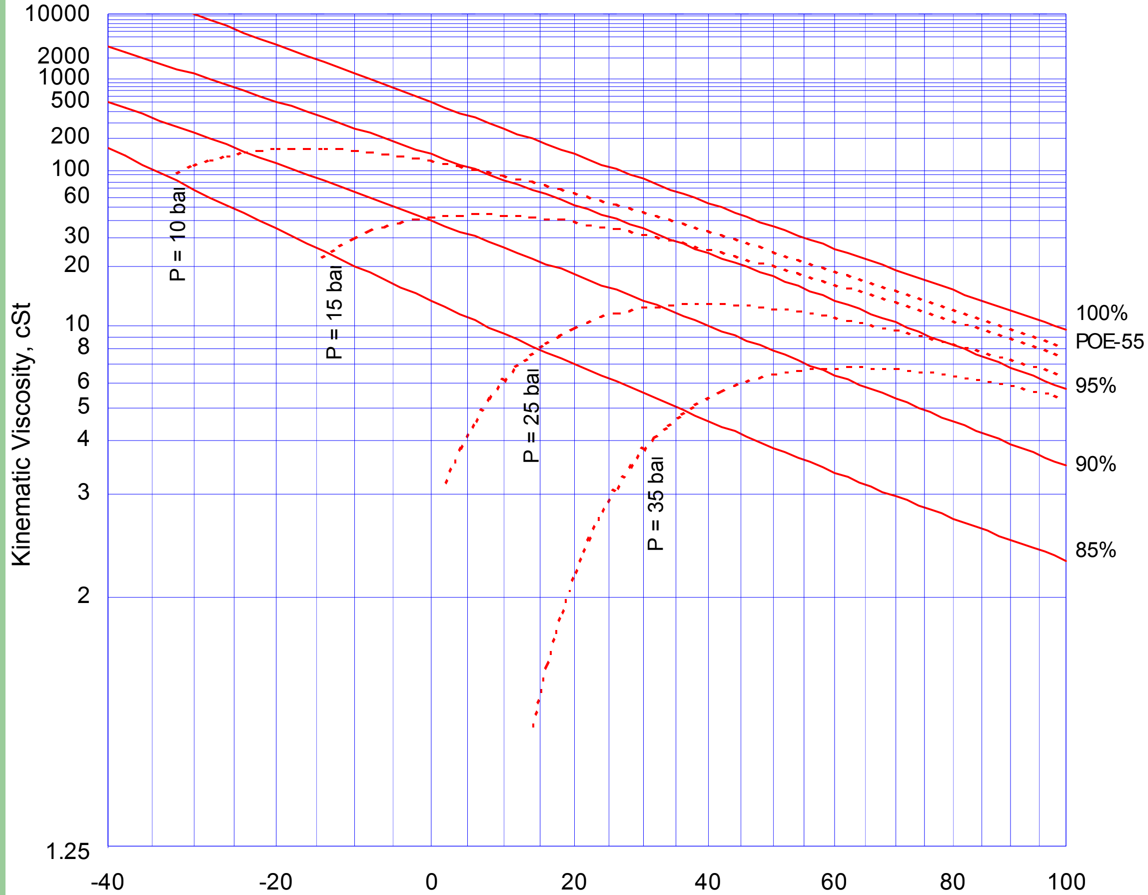
Modified Clausius-Clapeyron

$$\log(P) = D + \frac{E}{T} + \frac{F}{T^2}$$

Mixture Viscosities – 90% Lubricant
PAG > PAO > POE > AB



POE-55 / CO_2 Daniel Chart



Assume:

Evaporator = 0°C

Suction Pressure = 35 bar

10°C Superheat

10°C Internal Heat Exchanger

20°C Rise in Compressor

Bearing Lubrication Temp.

40°C

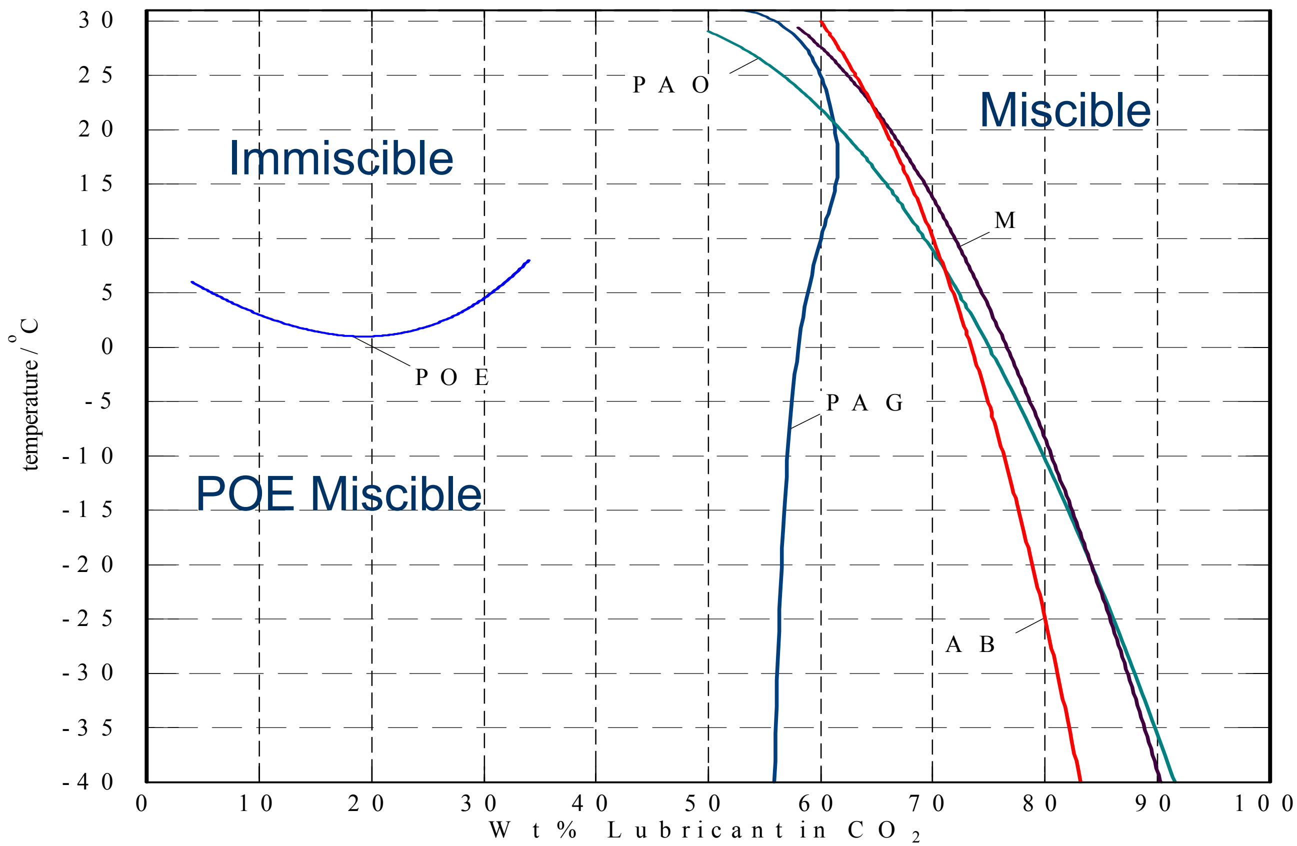
Pure Lubricant Viscosity

55 cSt

Mixture Viscosity

5.5 cSt

Miscibility in CO_2



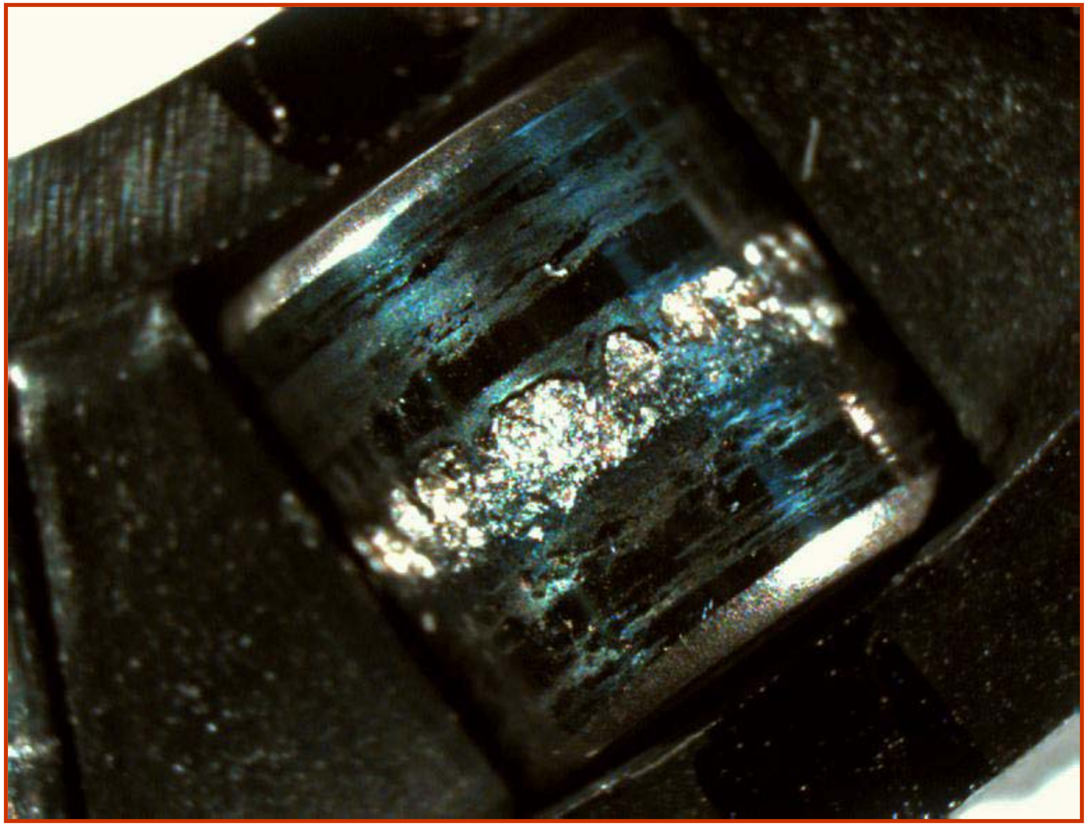
CO_2 Miscibility

- Based on miscibility data design concerns should be based on the cycle operation for the AB, MO, PAO, and PAG lubricants
- It is expected that the POE lubricant will not experience these miscibility problems
  - HOWEVER, serious design considerations must be weighed to account for the reduction in the mixture viscosity

Lubricants with CO2 - Conclusions

- POE Lubricant type showed good miscibility
  - Severe viscosity reduction possibly limits its use to low temperature cascade systems
- PAG, PAO, MO and AB are only partially soluble in CO_2
  - Transcritical AC systems Ø evaporators, receivers, Int. HX
  - Transcritical Heat Pump systems Ø evaporators, receivers, compressor sump
- However, the PAG type lubricant seems to give the best lubricity for transcritical applications
  - PAG maintained the highest mixture lubricity in this study
- High efficiency oil separators may make MO a viable lubricant in some cascade systems

Lubrication
Influence of CO_2- Roller Bearing

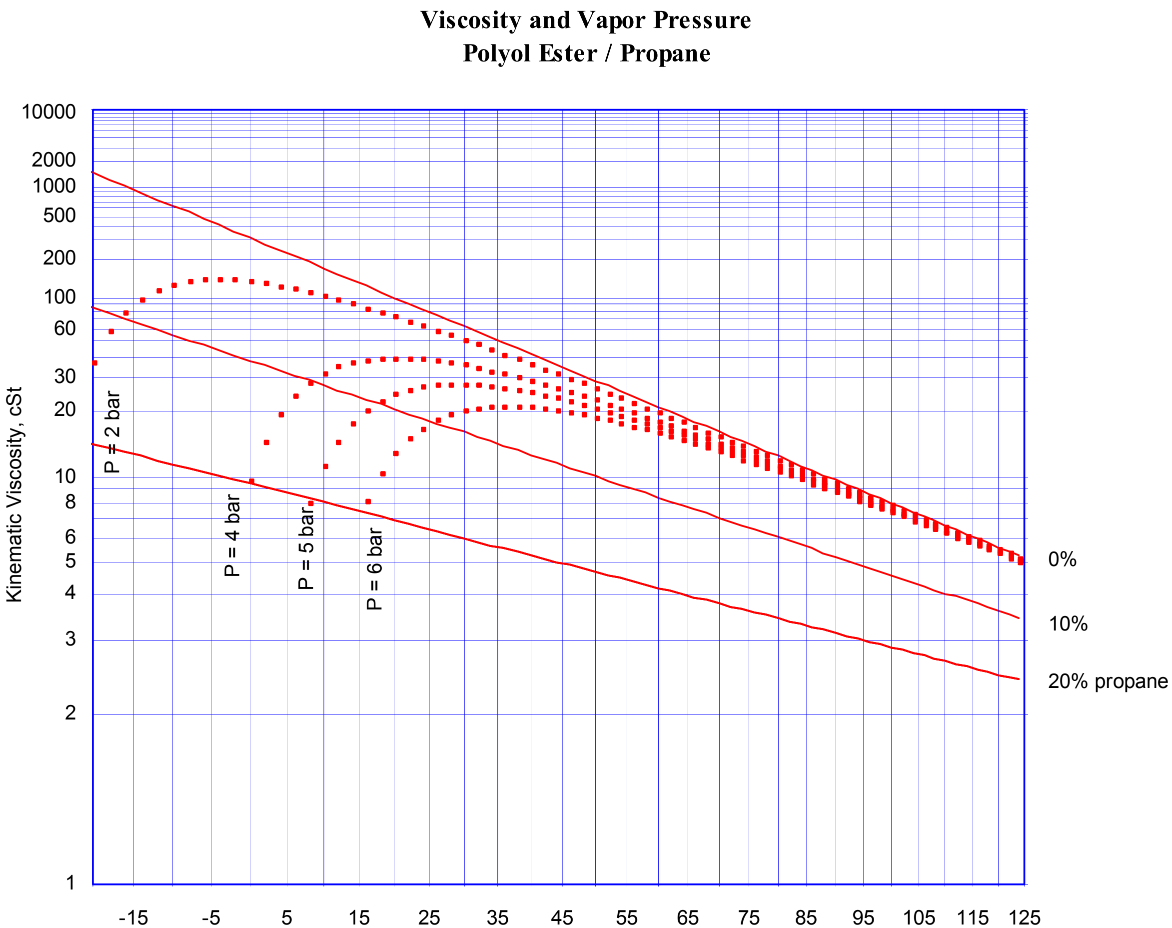


Prototype AC Compressor failed @ 10 hrs

Repeatable

POE-220

Polyol Ester 32 / Propane
Daniel Chart



Assume:

Evaporator = -6°C

Suction Pressure = 4 bar

6°C Superheat

10°C Suction Line HX

20°C Rise in Compressor

Bearing Lubrication Temp.

30°C

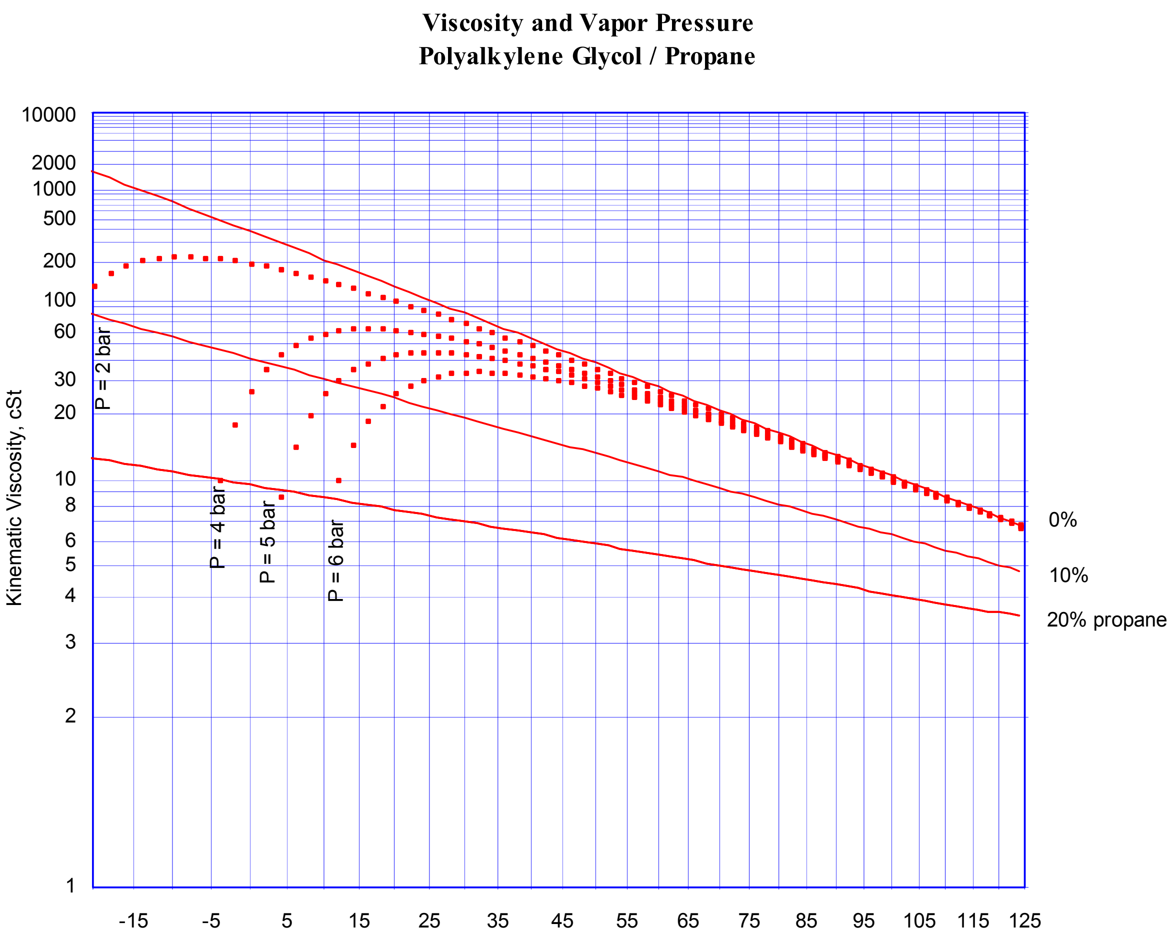
Pure Lubricant Viscosity

62 cSt

Mixture Viscosity

38 cSt

Polyalkylene Glycol 46 / Propane
Daniel Chart



Assume:

Evaporator = -6°C

Suction Pressure = 4 bar

6°C Superheat

10°C Suction Line HX

20°C Rise in Compressor

Bearing Lubrication Temp.

30°C

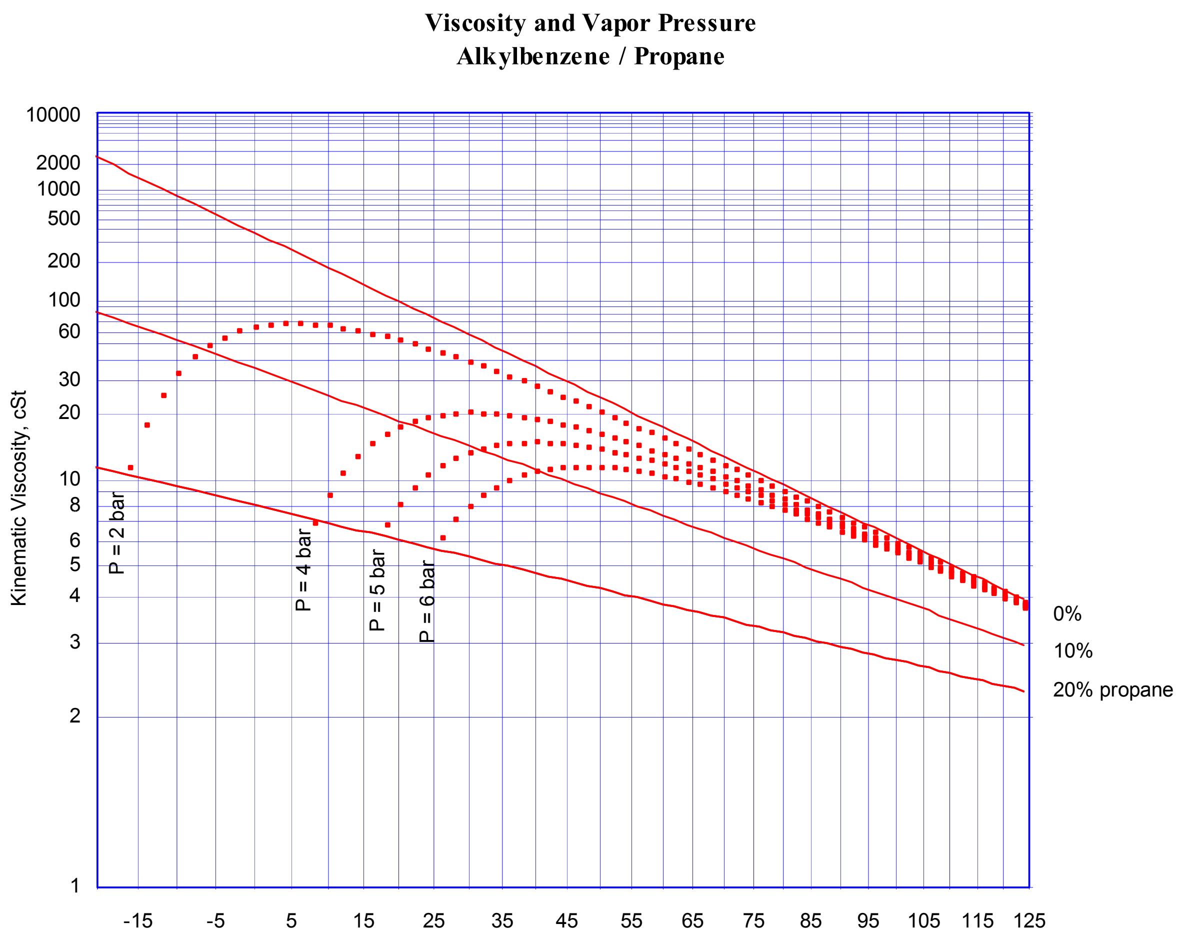
Pure Lubricant Viscosity

83 cSt

Mixture Viscosity

51 cSt

Alkylbenzene 32 / Propane
Daniel Chart



Assume:

Evaporator = -6°C

Suction Pressure = 4 bar

6°C Superheat

10°C Suction Line HX

20°C Rise in Compressor

Bearing Lubrication Temp.

30°C

Pure Lubricant Viscosity

60 cSt

Mixture Viscosity

20 cSt