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

Daniel Chart

Viscosity and Vapor Pressure
Naphthene Mineral Oil / Propane
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
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 of Naphthene Mineral Oil / Propane

Temperature (C)
Density (g/cc)

0% Pure MO
5%
10%
15%
20%
30% Propane
Density
Polyalkylene Glycol 46 / Propane

Density of Polyalkylene Glycol / Propane

Temperature (C)
Density (g/cc)

0% Pure PAG
5%
10%
15%
20%
30% 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

Absolute Viscosity, m Pa*sec
POE-55 / CO₂
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 CO₂
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 CO₂
  - Transcritical AC systems
  - Transcritical Heat Pump systems
- 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 CO₂- Roller Bearing

Prototype AC Compressor failed @ 10 hrs
Repeatable

POE-220
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
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
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