A Critical Assessment of Synthetic Lubricant Technologies for Alternative Refrigerants

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Introduction

- *iso*-Butane R-600a (C_4H_{10})
- Carbon Dioxide R-744 (CO_2)
- Ammonia R-717 (NH_3)

iso-Butane R-600a (C_4H_{10})

Mineral Oil Issues

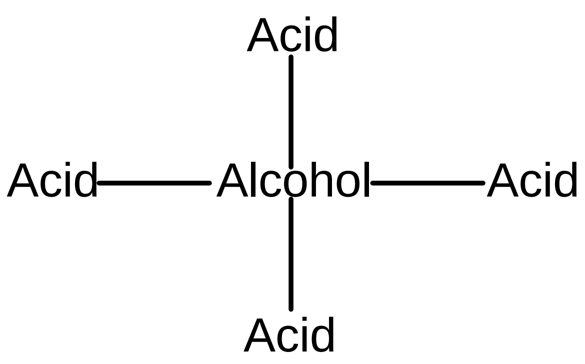
- ISO 10 to 22 mineral oils commonly used for R-600a. However, some issues have been observed related to the excessive solubility of R-600a in mineral oil
  - Foaming
  - Oil slugging (solubility: MO > esters > PAGs)
  - Reduction in energy efficiency
- Diester lubricant technology offers several advantages
  - Excellent lubricity
  - Reduced oil solubility
    - Reduced foaming
    - Improved energy efficiency of up to 5 %
  - Biodegradability

Chemistry of Diesters and POEs

Diester

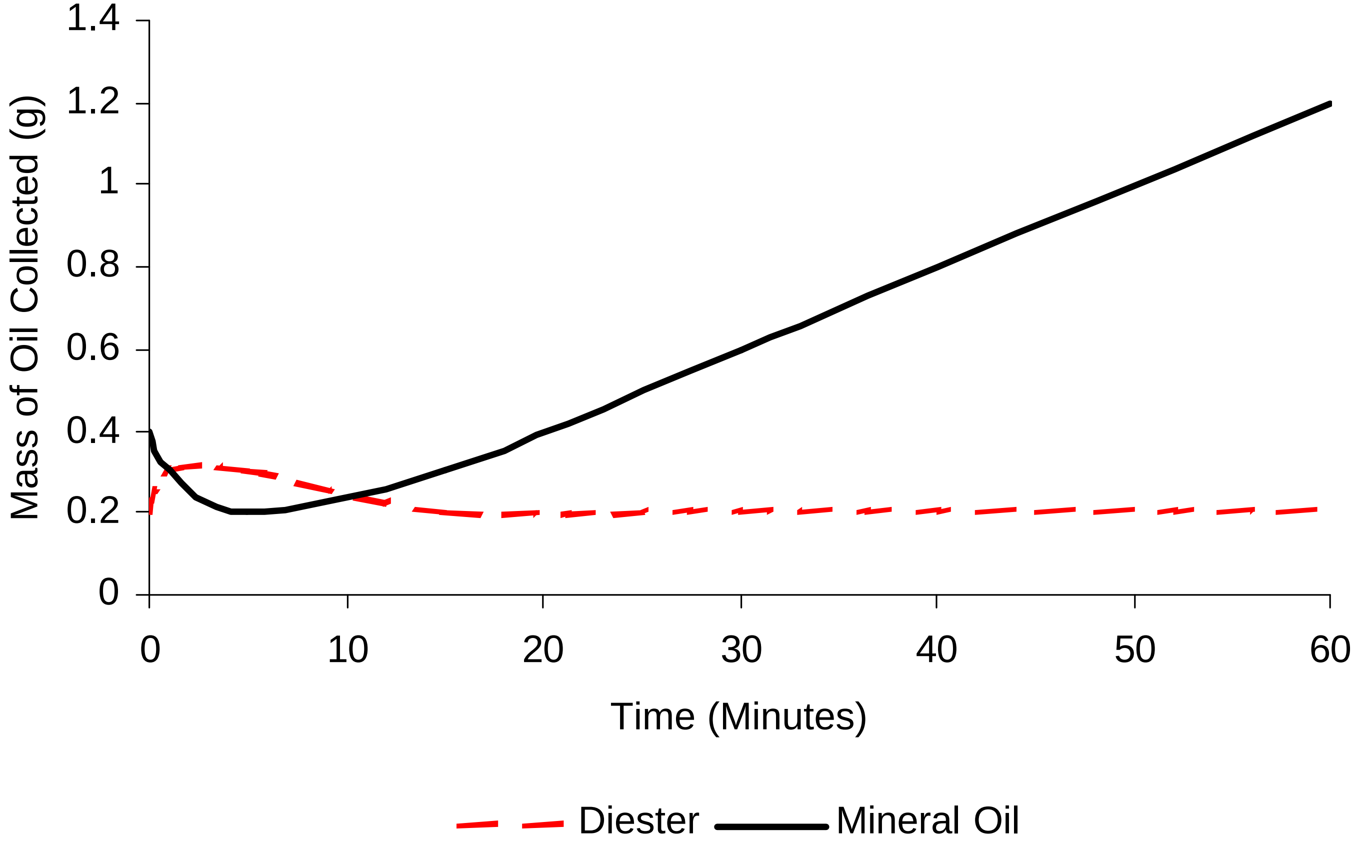
- Diesters are less expensive than POEs

Polyol esters (POE)



- POEs are more soluble than Diesters

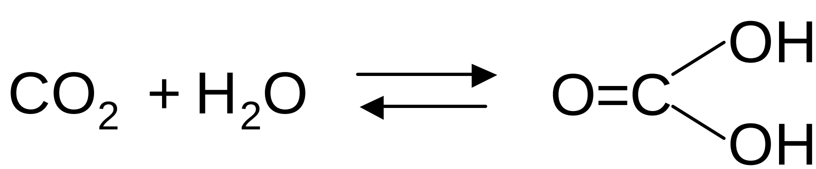
R-600a Lubricant Circulation Test



Carbon Dioxide R-744 (CO_2)

CO_2 Lubricant Issues

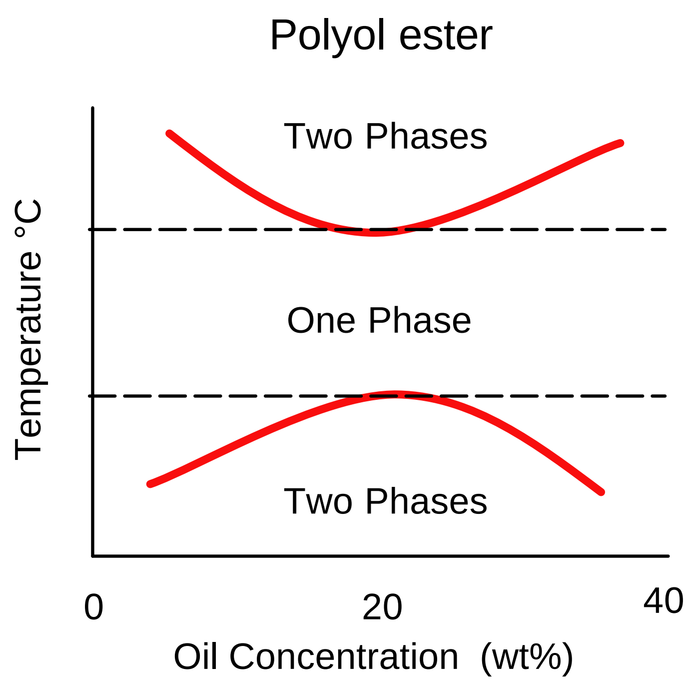
- Oil Transport
  - Oil Solubility
- High Pressure / High Load
  - Wear Performance
- Higher Level of water in Gas and Oil
  - Formation of carbonic acid from the reaction of carbon dioxide and water

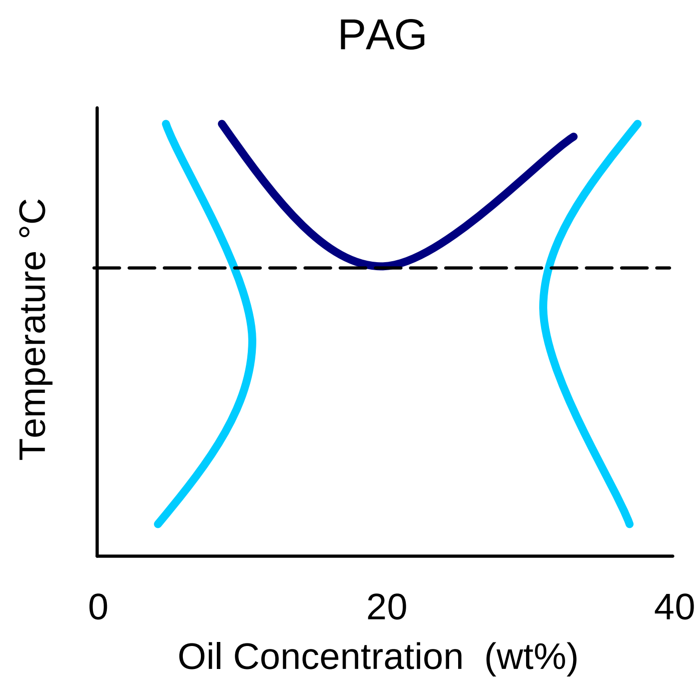


  - Effectiveness of drier

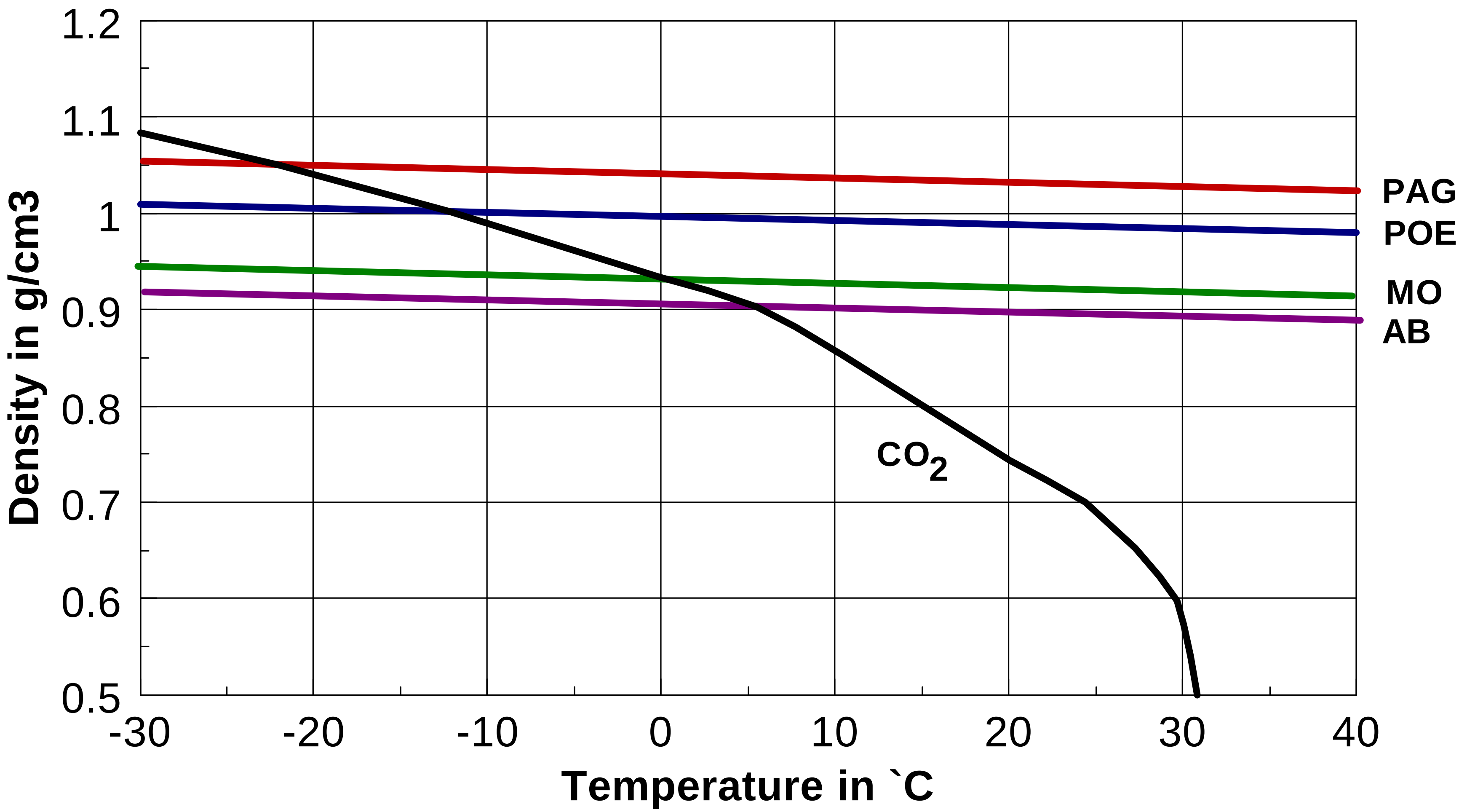
Schematic of CO_2 Miscibility Behaviour

Lubricant	Miscibility
Mineral Oil	Immiscible
PAO & AB	Immiscible
Diester & POE	Miscible
PAG	Partial



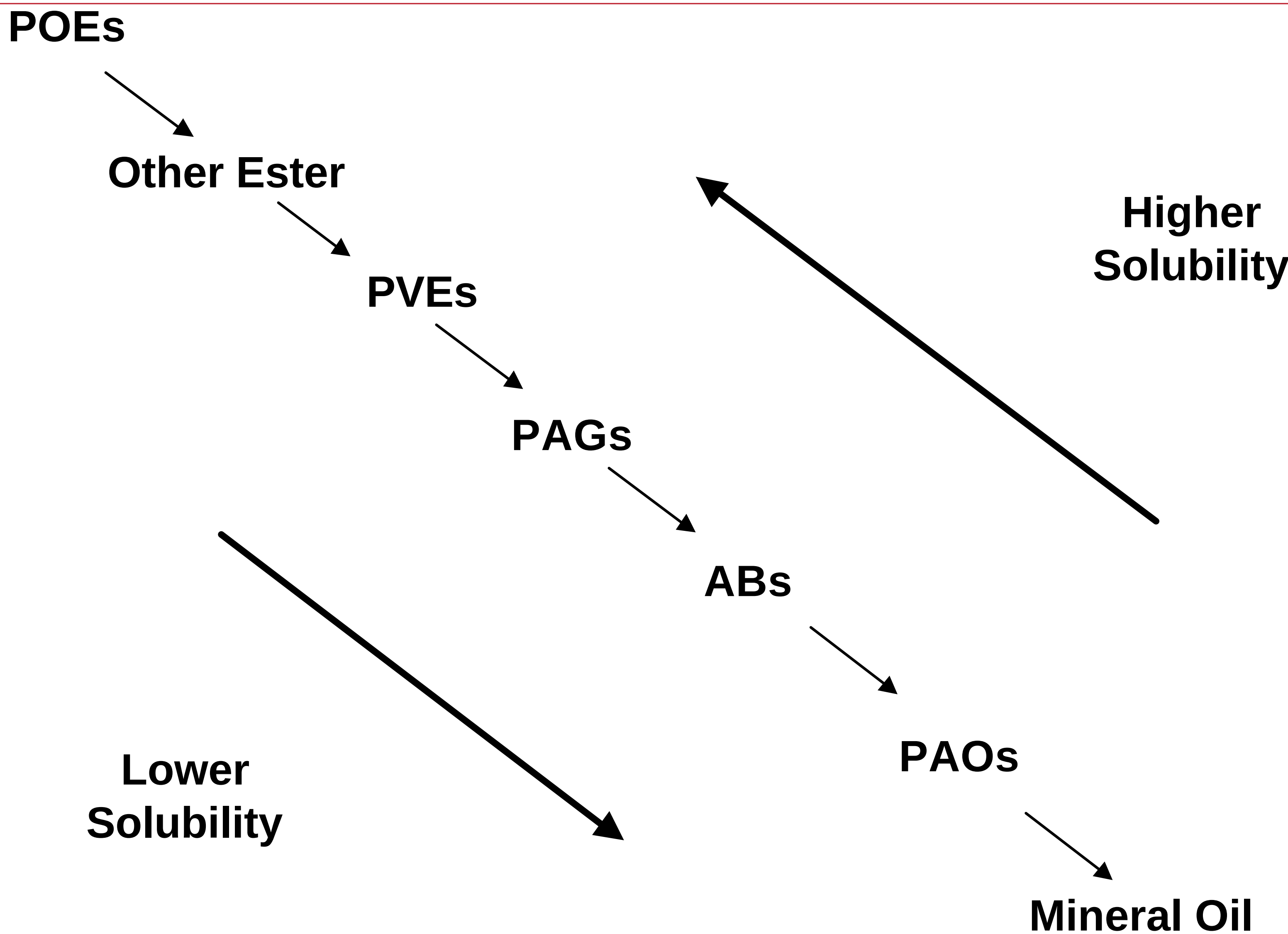


CO_2 / Lubricant Phase Inversion

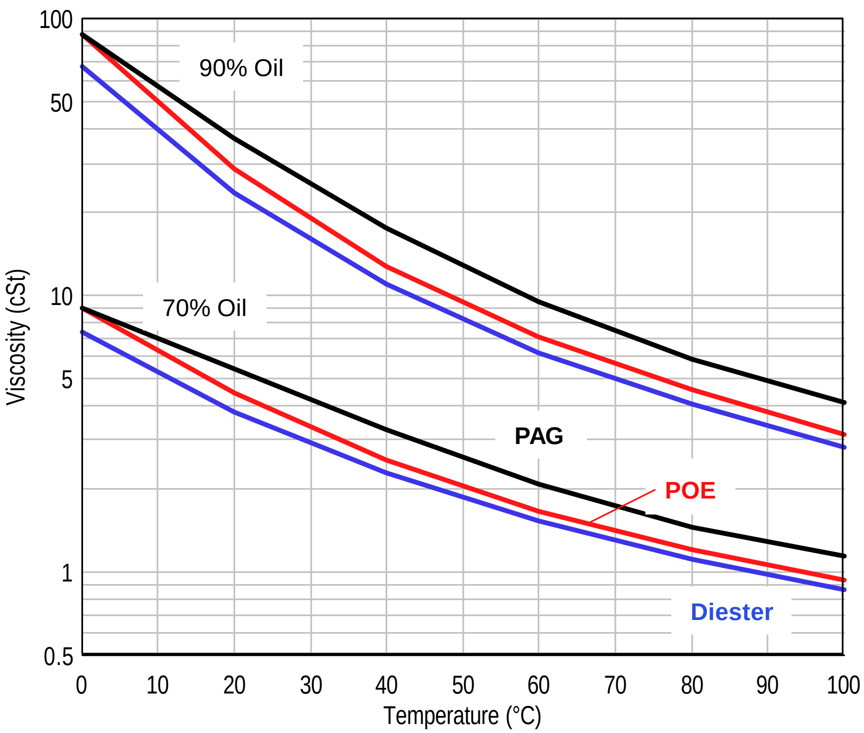


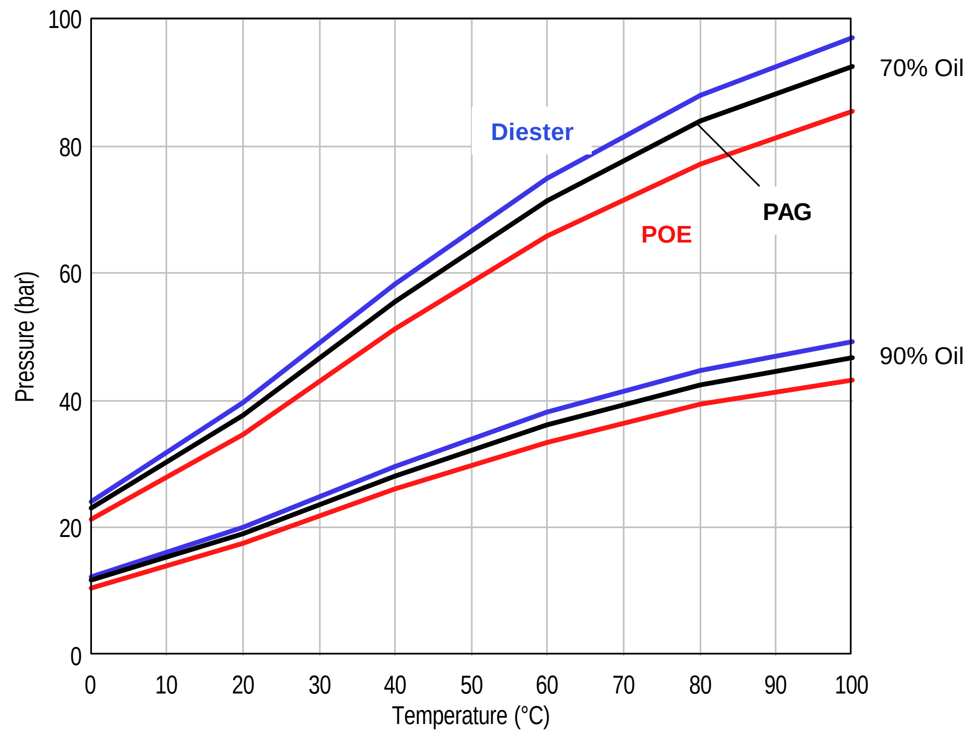
`.Hagita et al, Kobe, December 2000

Overview of CO_2 Solubility

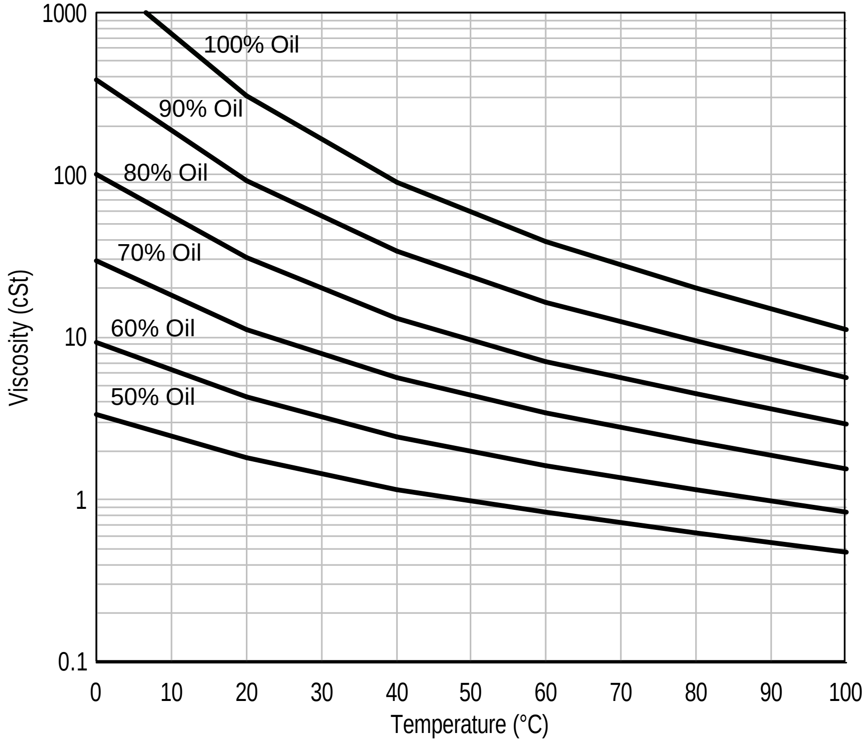


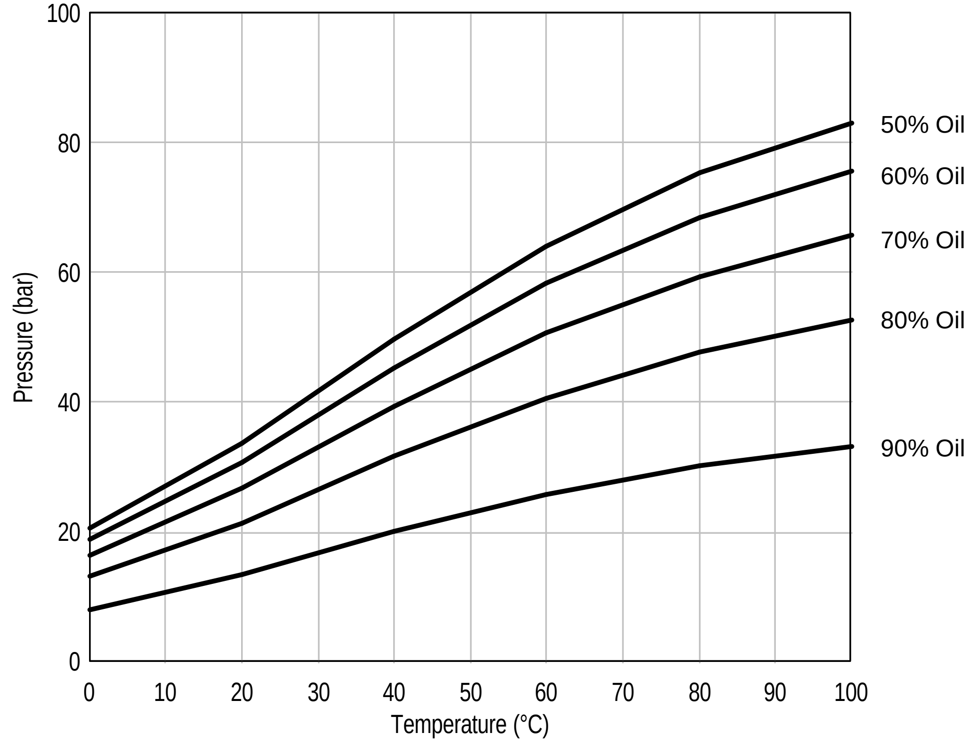
Vapour Liquid Equilibria Data:
CO_2 with ISO 32 POE, Diester & PAG





Vapour Liquid Equilibria Data: CO_2 with ISO 100 POE





Overview of CO_2 Lubricants

- Mineral oil (MO)
  - Very poor miscibility and solubility
    - Oil return and heat transfer issues
  - Phase inversion
    - Oil separation issues
- Poly α-olefin (PAO) & alkyl benzene (AB)
  - Experience with process gas applications
  - Poor miscibility and solubility
  - Phase inversion

Overview of CO_2 Lubricants

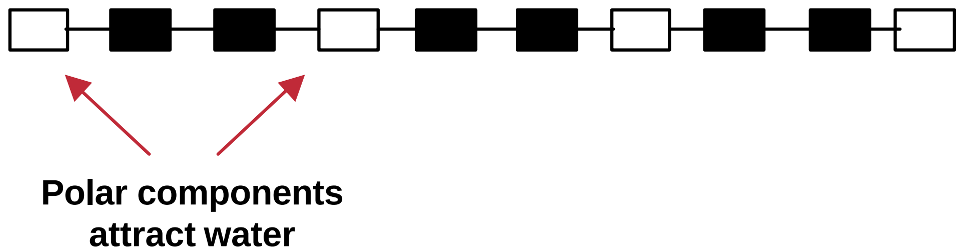
- Diester
  - Esters have a very high solubility
    - may need to use higher viscosity grades.
  - Hydrolytic stability
  - Have been used for a number of years in CO_2 process gas applications
- Polyol ester (POE)
  - As for diesters but greater stability and cost

Overview of CO_2 Lubricants

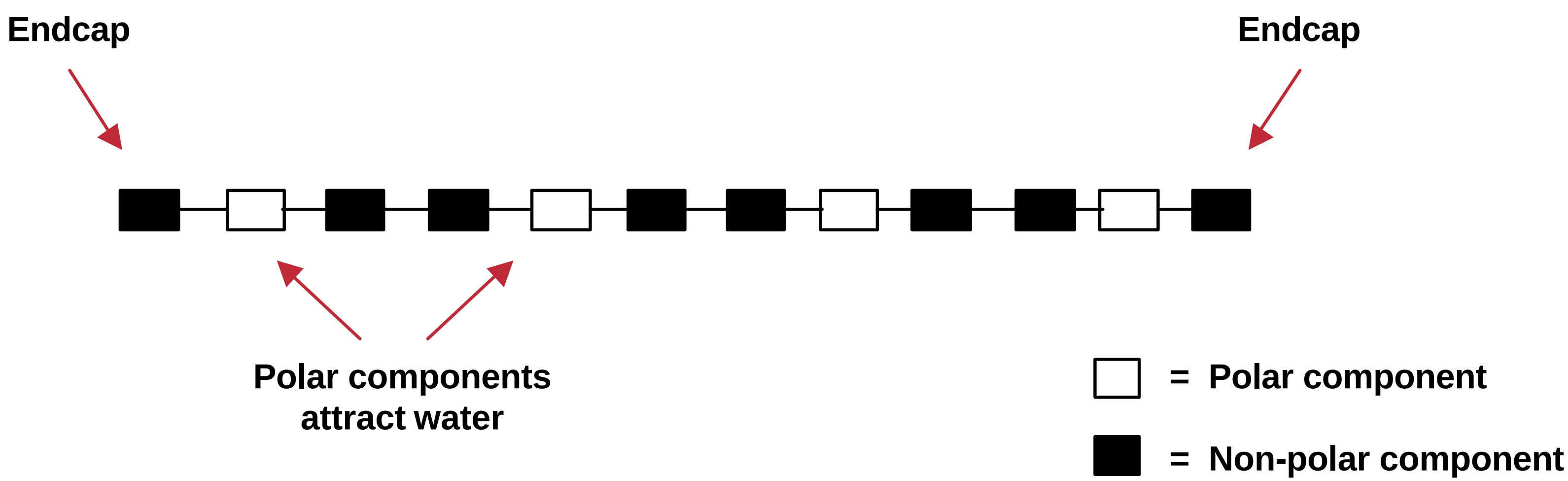
- Single end capped PAG
  - Have been used for a number of years in CO_2 process gas applications
  - High levels of water in the oil
    - Dielectric strength
    - Material issues (e.g. PET)
  - Stability ?
- Double end capped PAG
  - Work well in automotive applications and overcome many of the above problems
  - Greater stability and reduced moisture sensitivity when compared to single-end capped

Chemistry of Polyalkylene glycols (PAG)

Polyalkylene glycol (PAG) - non end-capped



Polyalkylene glycol (PAG) - double end-capped



CO_2 Lubricant Additive Issues

- Wear
  - High load may need addition of anti-wear additive
- Copper Plating
  - Are copper deactivators required?
- Foaming
  - Very high solubility of esters, in certain systems, may require use of anti-foaming agents

Overview of Oil Use

- Ester, PAGs, PAOs and blends of these with other oil are all under evaluation.
  - Double end-capped PAGs are approved and used for:
    - Automotive sector
    - Heat pumps
  - Polyol esters and diesters are used for:
    - Heat pumps
    - Industrial & Commercial compressors
    - Vending machines

Ammonia R-717 (NH_3)

Overview of Ammonia Lubricants

- Poor solubility of hydrocarbons in ammonia
  - Mineral oil, PAO, AB
- Esters react with ammonia to form gels
  - Therefore should not be used
- PAGs have good solubility with ammonia. Double end capped EO/PO PAGs used
  - Low water uptake
  - Inverse solubility
  - Improved compatibility with mineral oil
  - Excellent stability

Overview of Ammonia Lubricants

- Flooded evaporators - Hydrocarbons
  - Blends of PAO, AB and hydrocracked oils
  - Poor miscibility with ammonia
    - Low foaming
    - Low dilution
- DX systems - Double end capped PAGs
  - Reduced refrigerant concentration (1:50)
  - Excellent heat transfer
  - Cost effective system

Conclusions

- Chemistry can be modified to optimise
  - Solubility
    - Wear, foaming, oil transport, heat transfer etc.
  - Stability
    - Drain interval
  - Materials compatibility
- Oil selection criteria is often based on logistical issues
  - One oil for several refrigerants e.g. CO_2 and CNG
- Synthetics offer a number of advantages for use with alternative refrigerants

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