Refrigeration Oils for Natural Refrigerants

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refrigerants delivered by mother nature

Refrigeration Oils for Natural Refrigerants Content

- General requirements
- Key characteristics – miscibility and viscosity
- RENISO refrigeration oils for
  - Natural refrigerants (NH_3)
  - Hydrocarbons (e.g. propane, propylene)
  - Carbon Dioxide (CO_2)
- Summary / outlook

Requirements for refrigeration oils

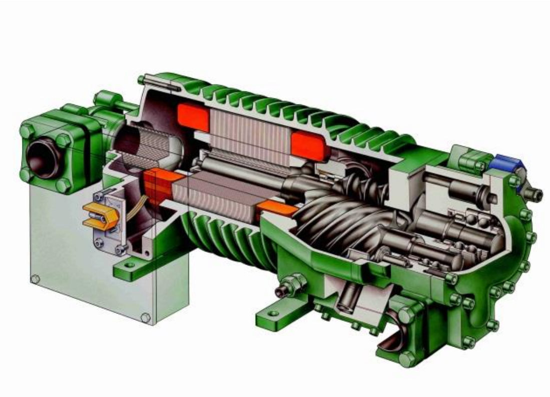


image: Bitzer

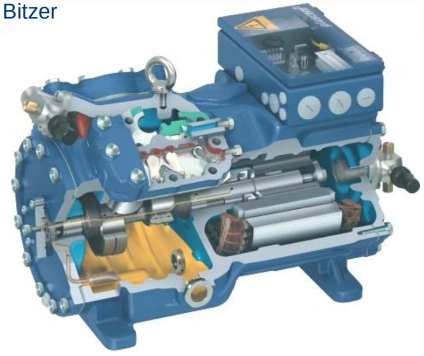


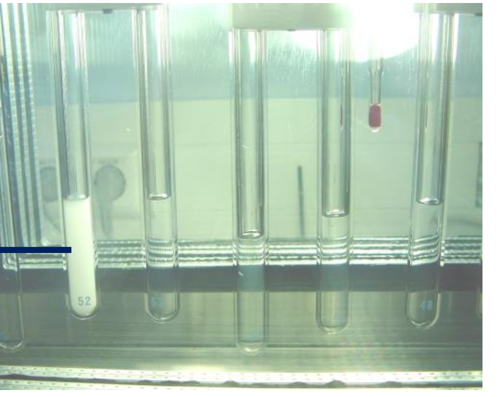
image: GEA Bock

- **Reliable lubrication properties (viscosity, antiwear performance)**
- **Good miscibility with refrigerants (oil transport, heat transfer)**
- **High chemical and thermal stability (in combination with refrigerant)**
- **Good compatibility with components (metals, plastics, elastomers)**
- **Reliable isolation properties (in hermetic compressors)**
- **Low water content**

Oil-refrigerant mixtures: „poor miscibility“ What does that mean ?

Poor miscibility = phase separation into
oil phase + refrigerant phase

Refrigeration oil with refrigerant
→ milky turbid emulsion

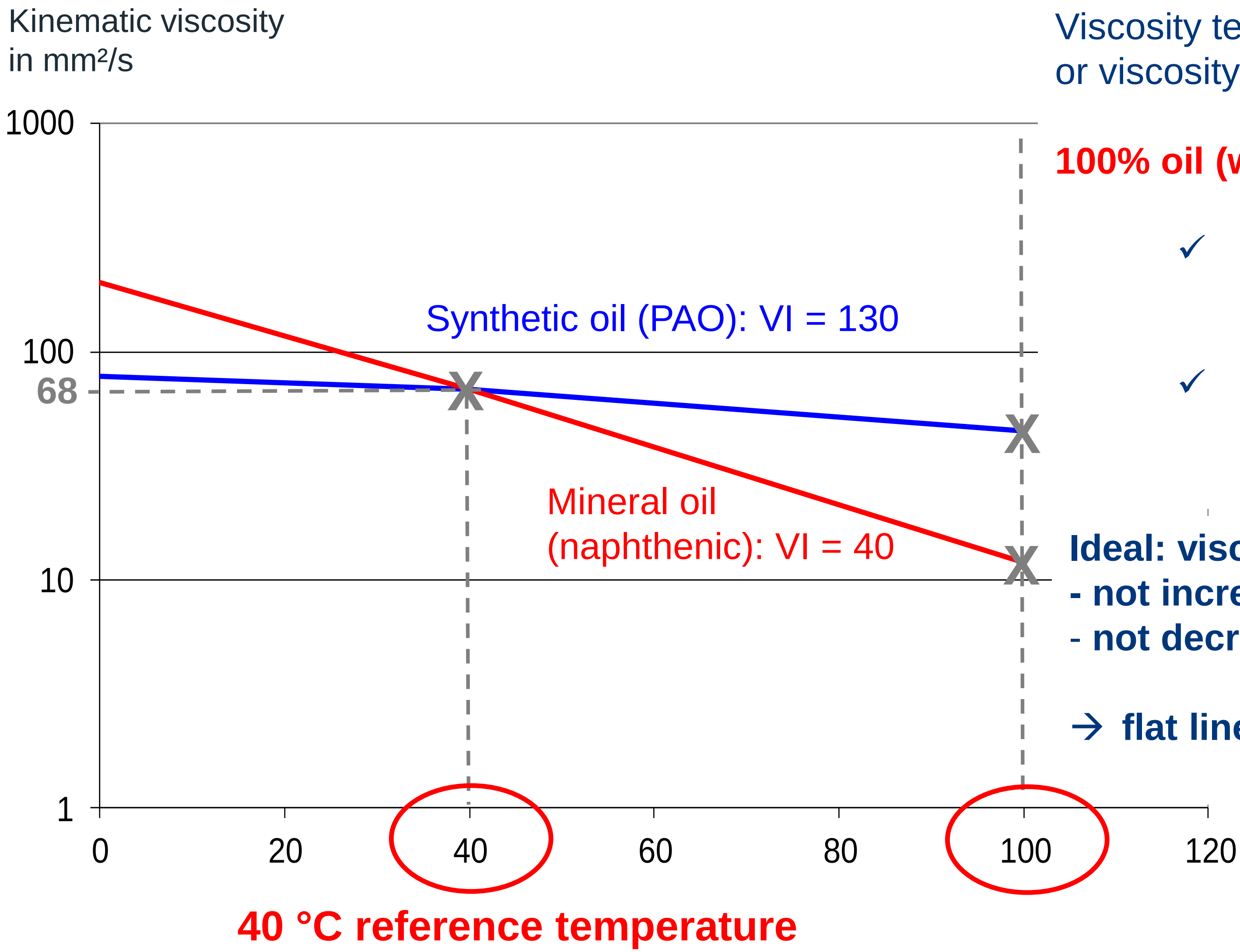


Refrigeration oil
(with poor miscibility)

Refrigerant
→ completely separated

Poor miscibility:
→ Negative impact on oil transport: Oil gets collected in the system → compressor is running dry
→ Negative impact on heat transfer: Insulating/blocking oil film → decrease in performance

Viscosity temperature diagram: Viscosity index (VI)



Viscosity temperature diagram or viscosity index (VI) describes:

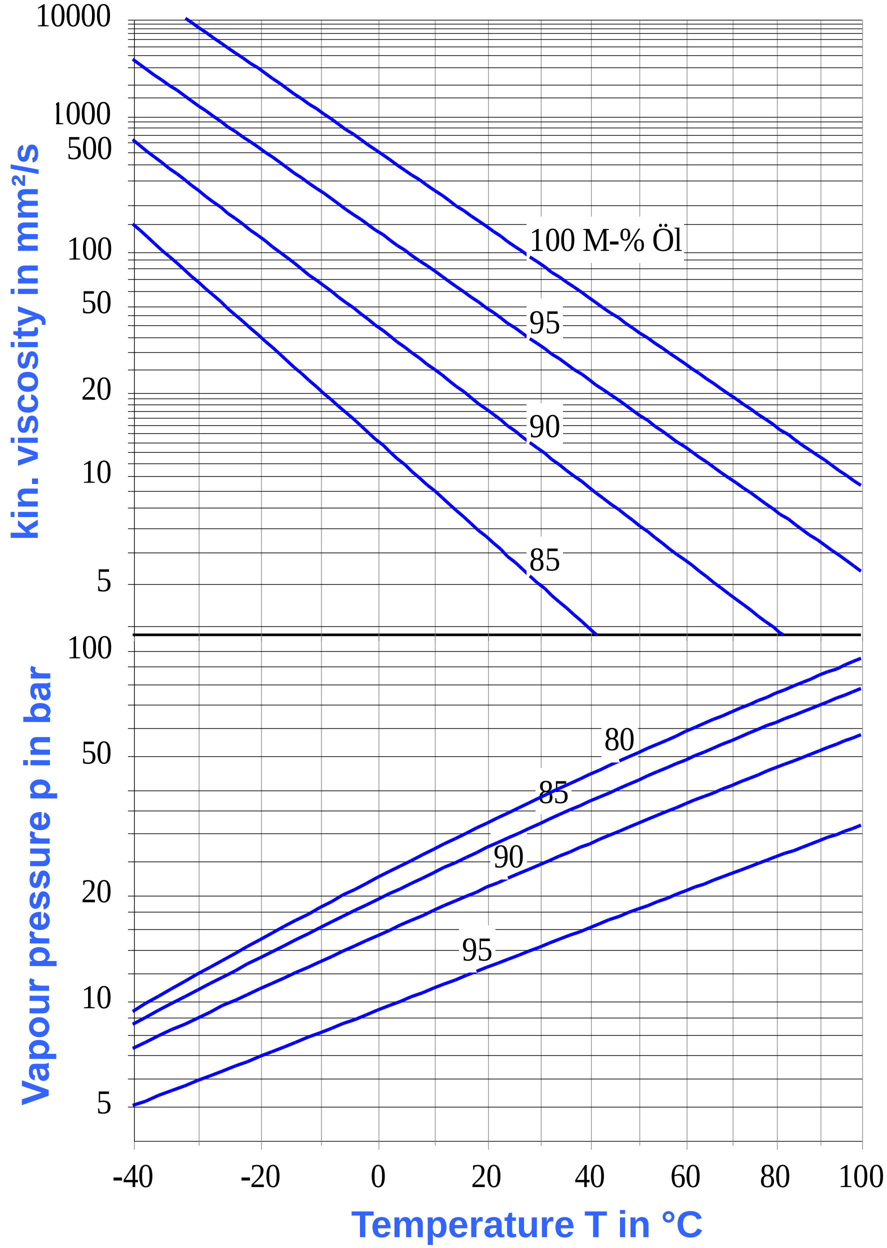
100% oil (without refrigerant)

- ✓ viscosity decreases with increasing temp.
- ✓ depending on the base oil type

Ideal: viscosity should …
- not increase at lower temp.
- not decrease at higher temp.

→ flat line / high VI (> 100)

PVT diagram (Pressure-Viscosity-Temperature)



The PVT diagram shows

Viscosity (V) of the mixture = Oil with dissolved refrigerant under operating conditions (p, T)

- ✓ Viscosity decreases with increasing content of refrigerant.
- ✓ The higher the pressure and the lower the temperature, the higher the refrigerant content.

Example diagram: RENISO C 55 E/CO_2
(concentration data in mass-% oil in CO_2)

RENISO refrigeration oils for

Ammonia (NH_3, R717)

Refrigeration oils for ammonia (NH_3)

Refrigeration oils based on mineral oils

„Classic“ refrigeration oils for ammonia: Naphthenic mineral oils

- **… good low temperature properties:**
  Based on naphthenic mineral oil
- **… world-wide available:**
  Long-term availability is secured

RENISO KM 32
RENISO KS 46
RENISO KC 68
RENISO KES 100
RENISO KW 150

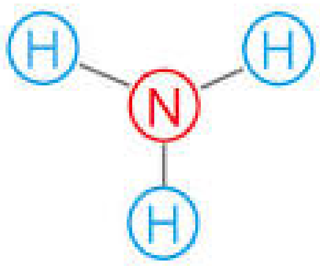
- **... compatibility and miscibility with all other NH_3 oils (except PAGs):**
  In every proportion
- **… very good compatibility with elastomers:**
  No problems with HNBR, NBR, CR elastomers
  → Proven seal compatibility with commonly used elastomers

Refrigeration oils for ammonia (NH_3)

Refrigeration oils based on PAOs…

…like:

RENISO UltraCool 68
RENISO Synth 68



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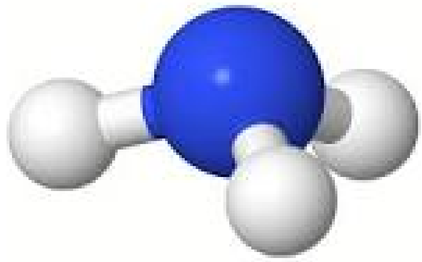


image: chemgapedia.deo

… surpass mineral oils with regard to:

- **Low temperature flowability → for lower evaporation temperatures**
- **Evaporation loss → for less oil consumption**
- **Thermal stability → for less deposits in compressors / filters**
- **Lifetime → for longer oil change intervals**

Refrigeration oils for ammonia (NH_3)

Refrigeration oil stability in contact with ammonia (DIN 51538)*

*oil ageing procedure acc. DIN 51538:
120 °C / 7d / NH_3 + air / steel coupons

Appearance of oil + tubes after test:

Mineral oil
RENISO KC 68

PAO
R.UltraCool 68

PAO
RENISO SYNTH 68

Mineral oil
(average)

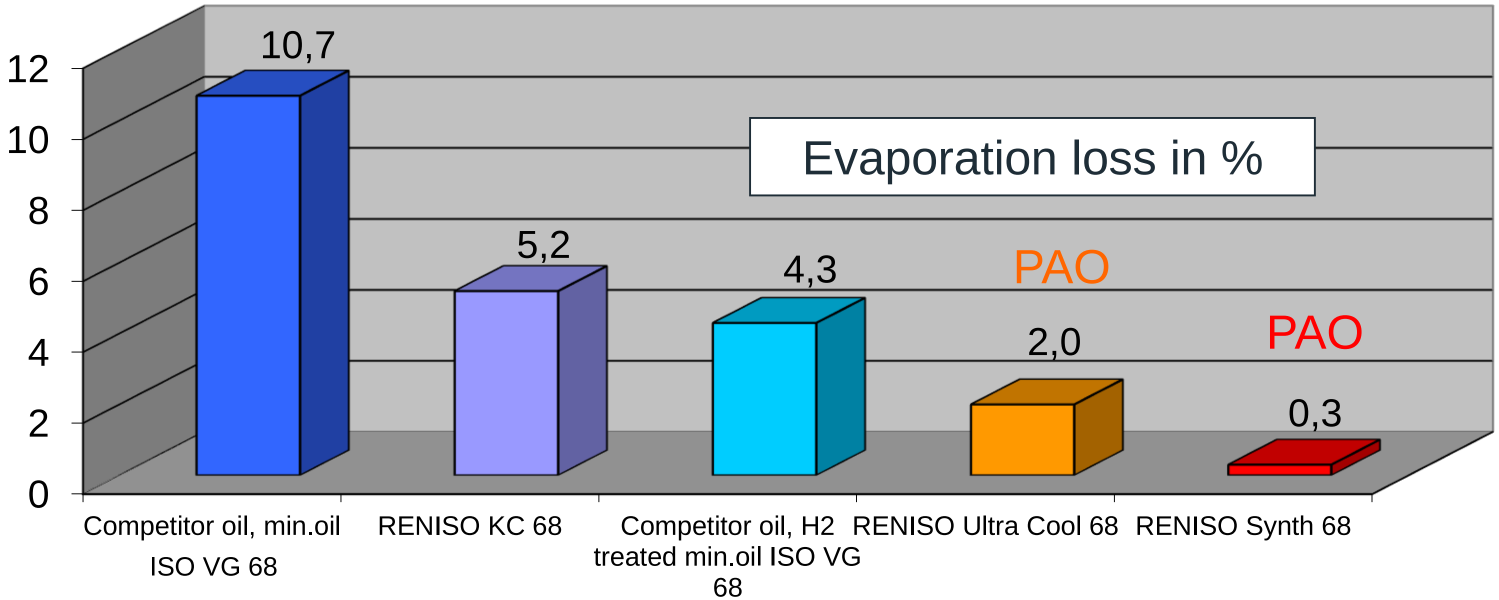
no deposits,
slight discoloration

no deposits,
no discoloration

deposits,
dark coloration

Refrigeration oils for ammonia (NH_3)
Evaporation loss (→oil carry over)

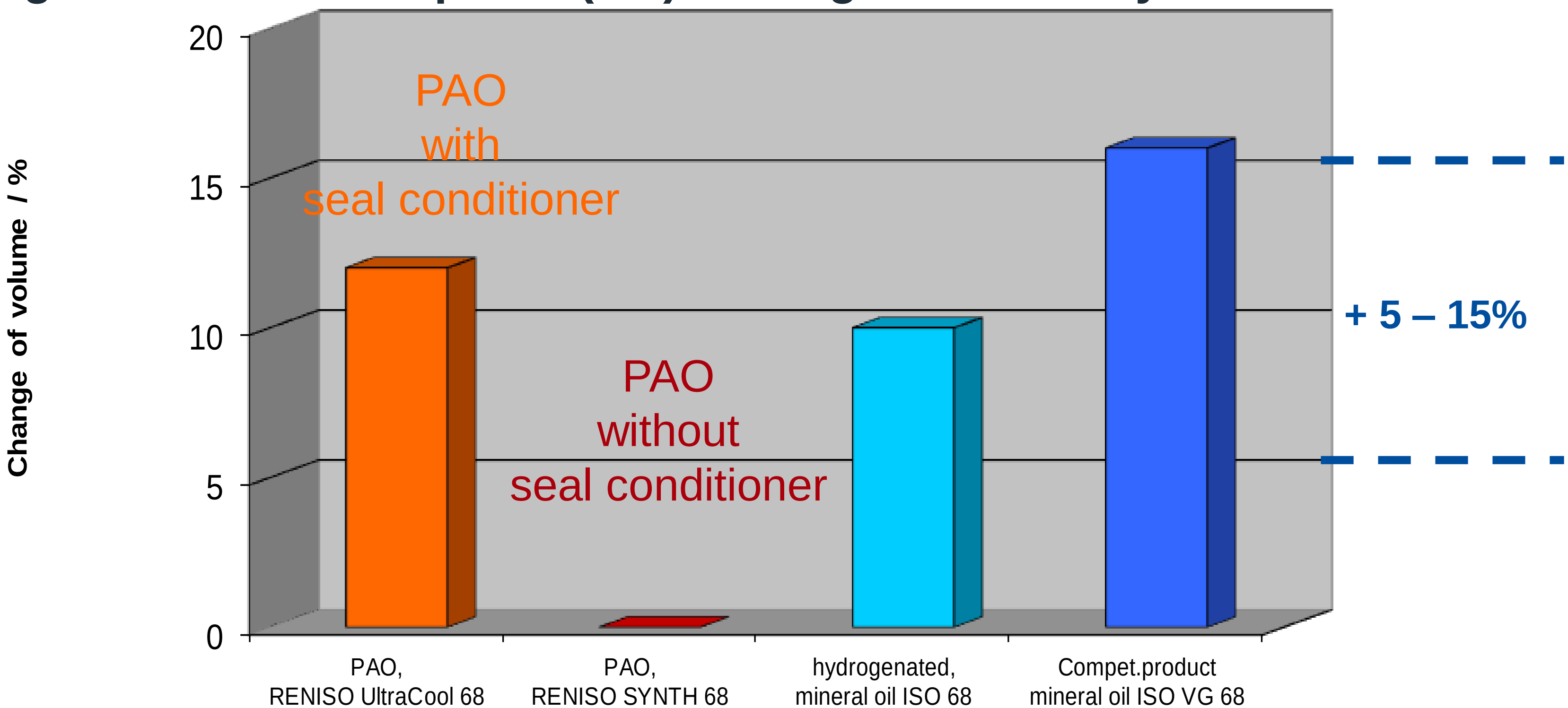
Evaporation loss acc. to ASTM D 972
150 °C / 22 h / air flow rate 2 l/min



Synthetic PAO refrigeration oils have lower evaporation losses than refrigeration oils based on mineral oil
→ less oil refilling quantities in the compressor

Refrigeration oils for ammonia (NH_3)
Sealing compatibility

Sealing material: Chloroprene (CR). Storage in oil: 7 days at 100 °C



Moderate swelling of 5 – 15% means:
No problems with oil leakage at the seal

→ **PAO without seal conditioner may perhaps cause problems with CR**

→ **Suitable are mineral oils and PAO with seal conditioner:**
RENISO UltraCool 68 and UltraCool 100

Refrigeration oils for ammonia (NH_3) based on synthetic PAO

ISO VG	Basis naphthenic mineral oil RENISO K				Basis synthetic oil PAO RENISO UltraCool			
		Kin. visc. at 40 °C [mm²/s]	Kin. visc. at 100 °C [mm²/s]	VI		Kin. visc. at 40 °C [mm²/s]	Kin. visc. at 100 °C [mm²/s]	VI
68	RENISO KC 68	68	7.4	58	**RENISO UltraCool 68**	62	9.1	124
100	RENISO KES 100	100	8.4	20	**RENISO UltraCool 100**	108	14.4	136
150	RENISO KW 150	150	10.9	27				
220	RENISO KX 220	220	13.6	25				

Synthetic PAO refrigeration oils provide high lubricating film thickness: also at high temperatures reliable lubrication ("High VI effect")
→ Suitable especially for heat pumps

Refrigeration oils for ammonia (NH_3)
Miscibility at higher temperatures (!)

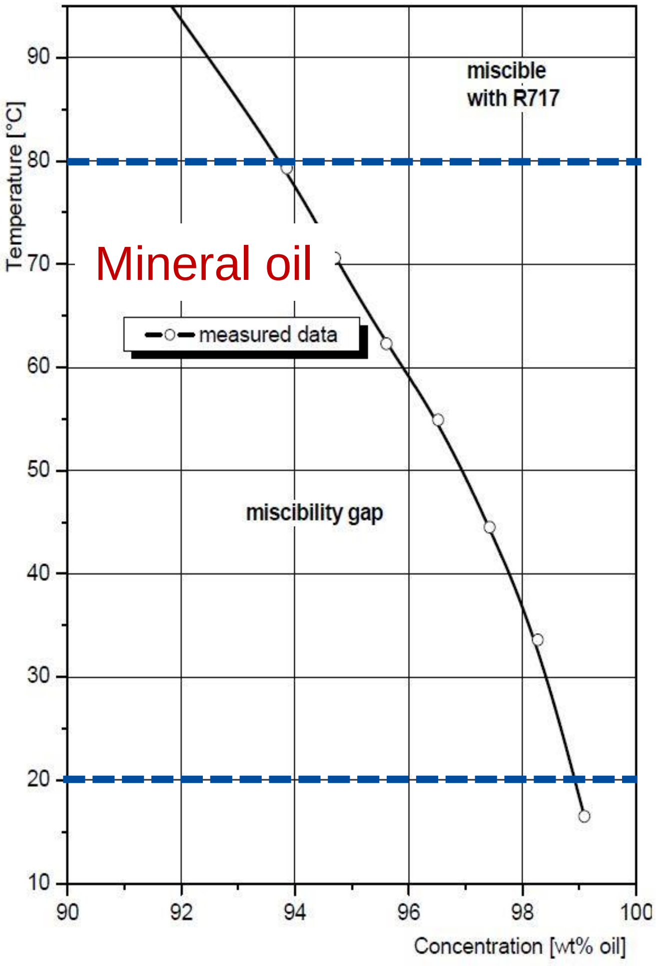


Fig. 4 Miscibility behavior in the system Reniso KC 68 – R717

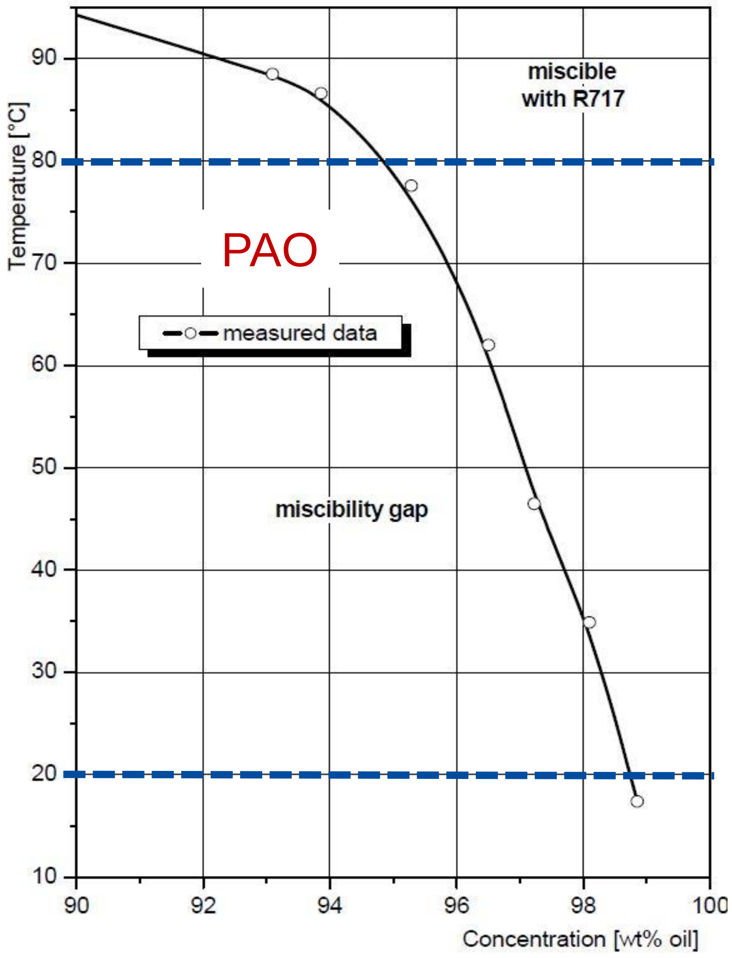
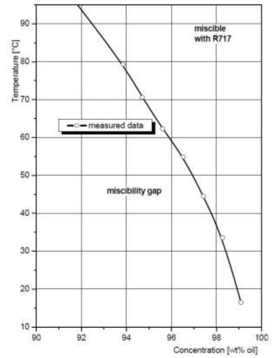


Fig. 2 Miscibility behavior in the system Reniso Synth 68 – R717

at 80 °C: up to 6.5% NH_3 are miscible with refrigeration oil

Refrigeration oils for ammonia (NH_3)
Maximum NH_3 concentration



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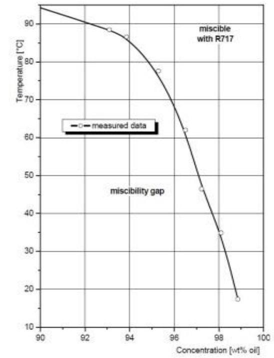


Fig. 2 Miscibility behavior in the system Reniso Synth 68 – R717

Temperature	Maximum NH_3 concentration in the oil/NH_3 mixture	
	Mineral oil RENISO KC 68	PAO RENISO SYNTH 68
< 0 °C	< 1%	< 1%
40 °C	2.2%	2.2%
60 °C	4.1%	3.4%
80 °C	6.4%	5.4%

→ **Also in „non-miscible“ NH_3 oils there can be a homogeneous mixture with ammonia at elevated temperatures.**

→ **Synthetic oils: less NH_3 is solved → less impact on viscosity**

Refrigeration oils for ammonia (NH_3) Miscibility and viscosity

How big is the influence of miscibility on the viscosity?

Please see here:

Forschungsrat Kältetechnik Project

FKT 208/17 Effect of the ammonia solubility on the viscosity of different refrigeration oils types

Examined oils:

- Mineral oil based
- PAO based (both in ISO VG 68)

Result:

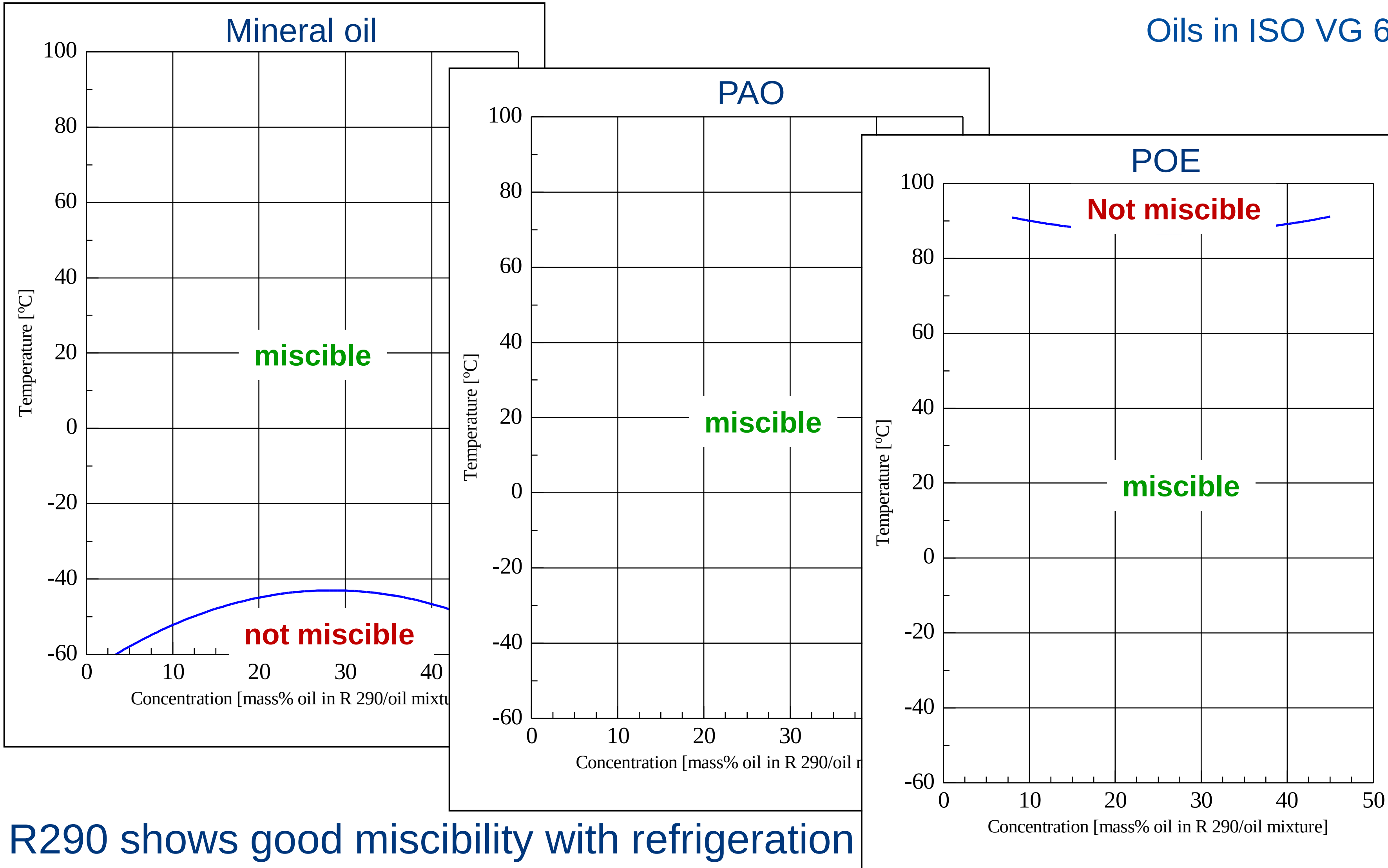
→ Mixture viscosity of PAO oils is in general higher compared to mineral oils

RENISO refrigeration oils for

Hydrocarbons (Propane, Propylene, Isobutane etc.)

Refrigeration oils for hydrocarbons
Miscibility with R290

Oils in ISO VG 68

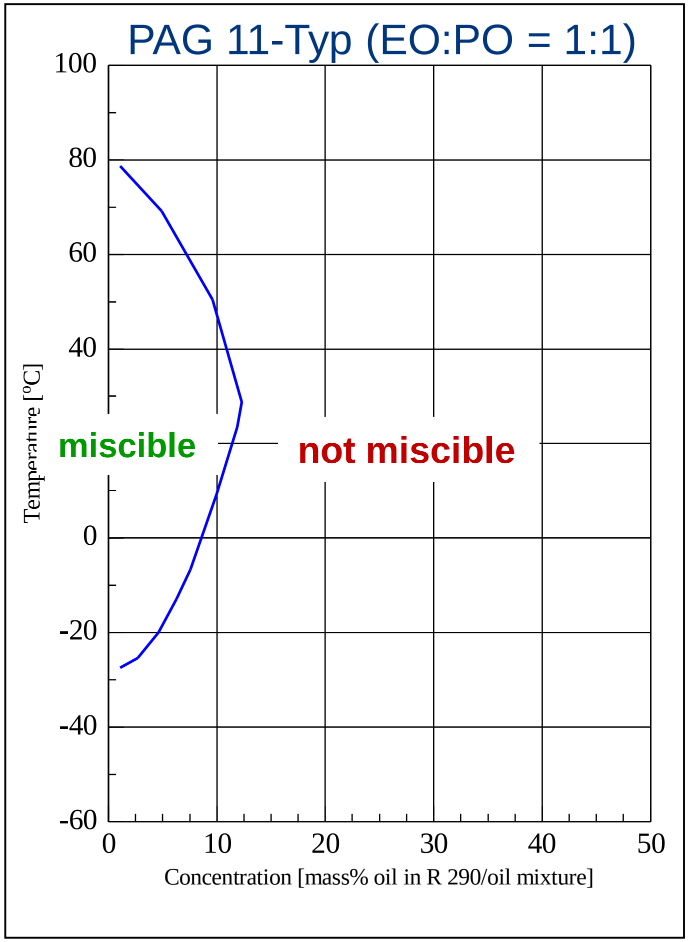


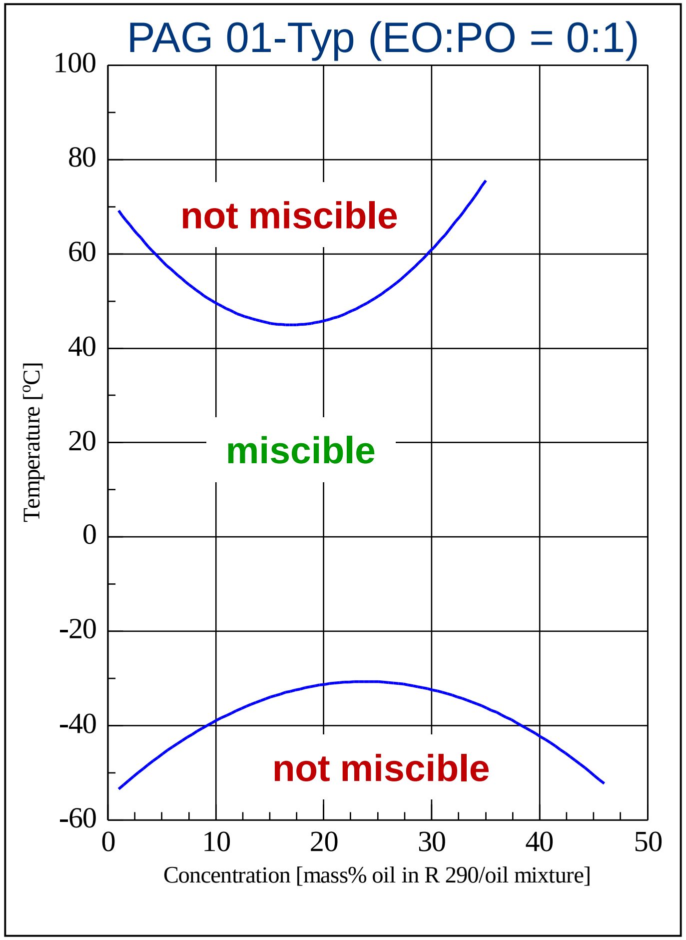
R290 shows good miscibility with refrigeration oils based on mineral oil, PAO or POE.

Refrigeration oils for hydrocarbons

Miscibility with R290

PAG: Miscibility depends on the chemical basic structure:
Relation ethylene oxide / propylene oxide in the molecule





Oils in ISO VG 68

Refrigeration oils for hydrocarbons:
R290 solubility and viscosity

		Without R290 40 °C	With R290 5 bar / 40 °C	
RENISO	**Base oil**	**kV [mm²/s]**	**Conc. [m% R290]**	**kV [mm²/s]**
KC 68	MO	68	8.0	12.0
SYNTH 68	PAO	68	9.0	18.5
SEZ 68	POE	68	6.5	28.0
PG 68	PAG	68	5.5	29.0

kV = kinematic viscosity

Different oil types show different degrees of solubility:

PAG and POE: Lower solubility and higher mixture viscosity
Mineral oil and PAO: Higher solubility / lower mixture viscosity (esp. MO)

→ PAG / POE best choice for hydrocarbons with regard to wear protection
PAG also have high VI (>200): additional benefits at high temperatures

RENISO refrigeration oils for

Carbon Dioxide (CO_2, R744)

Refrigeration oils for CO_2

R744 / CO_2 cooling applications

Stationary applications (cooling / refrigeration / heat pump):

- **Supermarket cooling (cascade and transcritical systems)**
- **Ship cooling**
- **Heat pumps (industrial and domestic use)**

Mobile applications (A/C): mainly projects

- **Passenger cars (Daimler, VW)**
- **Coaches**
- **Trains**

Refrigeration oils for CO_2

CO_2 miscibility of the refrigeration oil

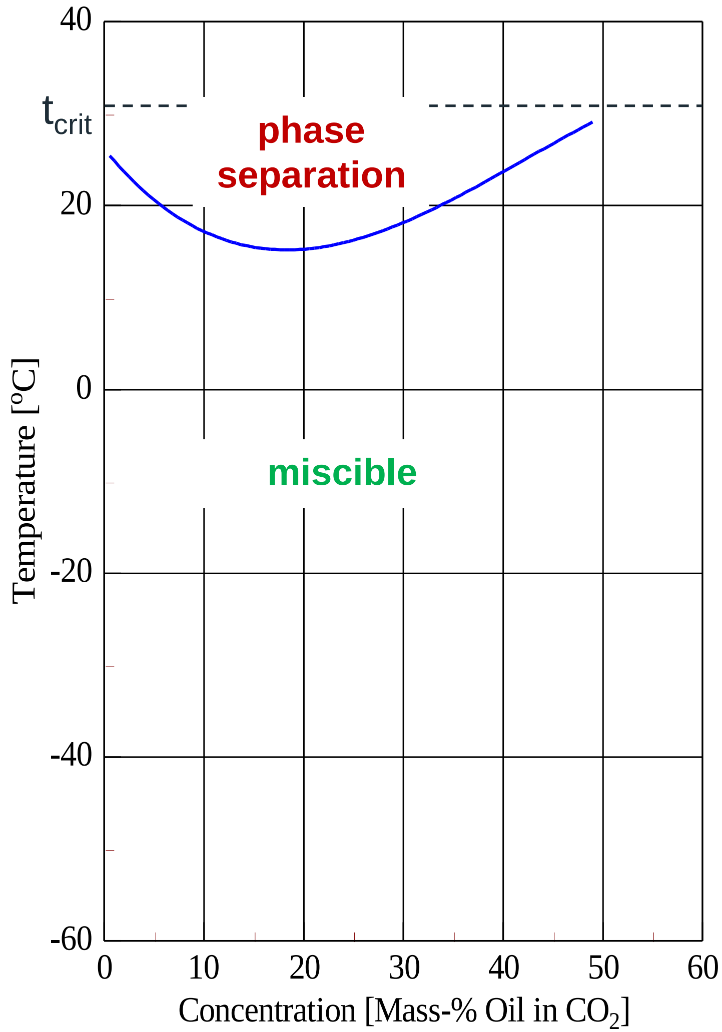
- → **Polyalphaolefins (PAO) oils are not miscible with liquid CO_2**
- → **Polyalkylene glycol (PAG) show a limited miscibility: used in compact systems (car a/c, heat pumps etc.)**
- → **CO_2 refrigeration oils based on polyol esters (POE): are the most important group because of the very good miscibility with CO_2**

Refrigeration oils for CO_2

RENISO C: CO_2 refrigeration oils based on POE

Excellent miscibility of RENISO C with CO_2

- **High flowability at low temperatures**
- **No negative impact on the heat transfer in the evaporator**
- **Safe oil transport back to the compressor also in large tubing systems (supermarket)**
- **No oil separator necessary**

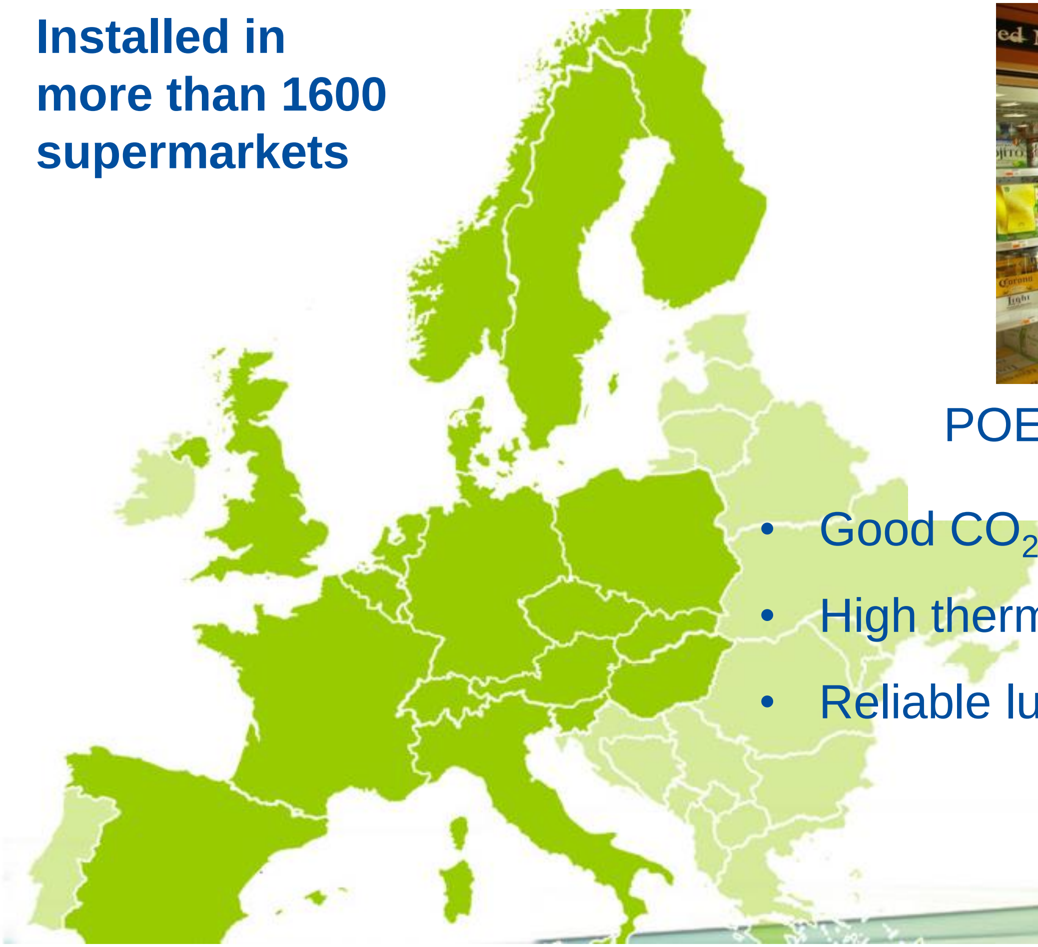


miscibility gap diagram RENISO C 85 E / CO_2

Refrigeration oils for CO_2

CO_2: Established technology in supermarkets in Central / Northern Europe

Installed in more than 1600 supermarkets



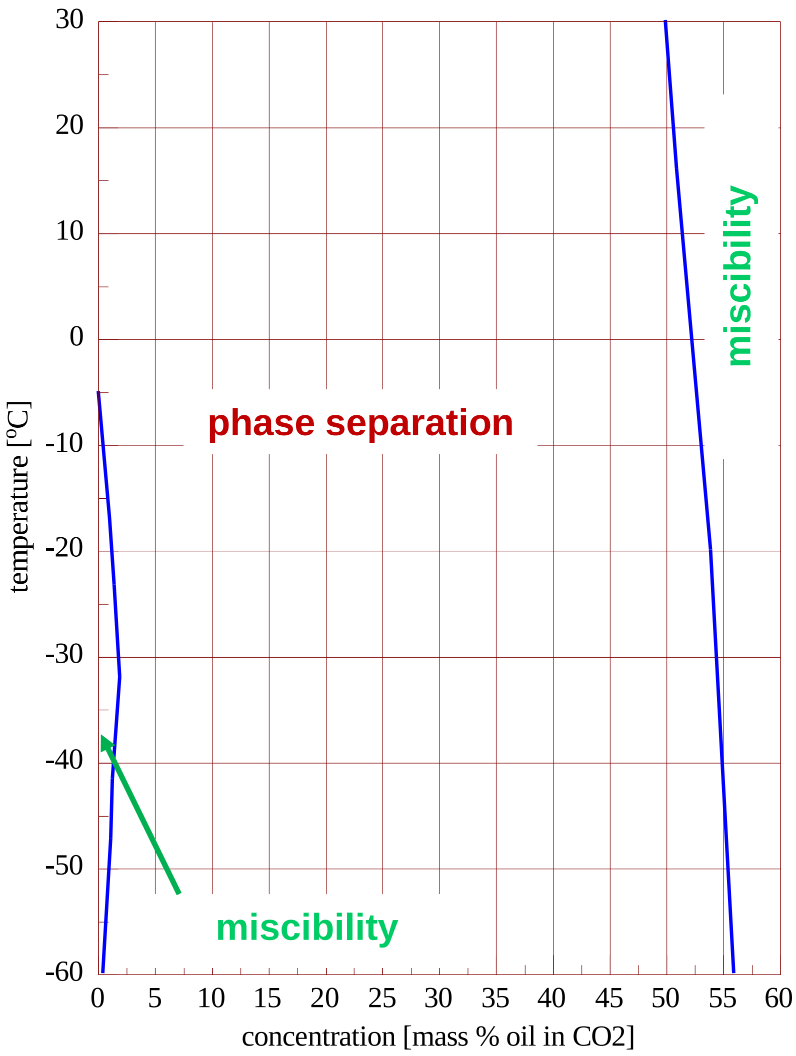
POE with special additive system for

- Good CO_2 miscibility (oil return, heat transfer)
- High thermal stability (transcritical)
- Reliable lubricating properties (high pressure)

Source: Carrier, Status August 2015
B. Heinbokel

Refrigeration oils for CO_2

RENISO ACC 68: CO_2 refrigeration oil based on PAG (double end-capped)



- Significant miscibility gap
- Use in compact cooling systems
- Lower dilution under CO_2 atmosphere: higher lubricant film thickness

→ Very good practical experience in heat pump and air conditioning applications

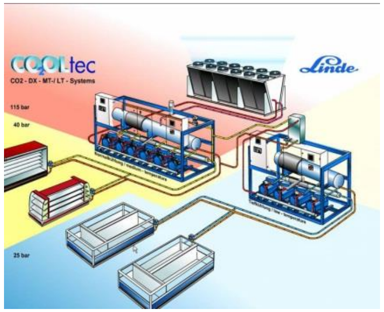
Refrigeration oils for CO_2

For carbon dioxide (CO_2, R744)

RENISO C: Based on POE
Special anti-wear additivation guarantees excellent lubricating properties

- **RENISO C 55 E:** subcritical,
  e.g. supermarket cooling
- **RENISO C 85 E:** subcritical / transcritical,
  e.g. supermarket cooling
- **RENISO C 170 E:** mainly in subcrit. screw compressors
  e.g. ship cooling

> 15 years of experience



⇨ **RENISO C oils are used in nearly all relevant CO_2 compressors in all regions**

RENISO ACC: Based on double end-capped PAG
incl. special anti-wear (AW) additives

- **RENISO ACC series:**
  For heat pumps and A/C applications
  (passenger car A/C e.g. Daimler, VW)

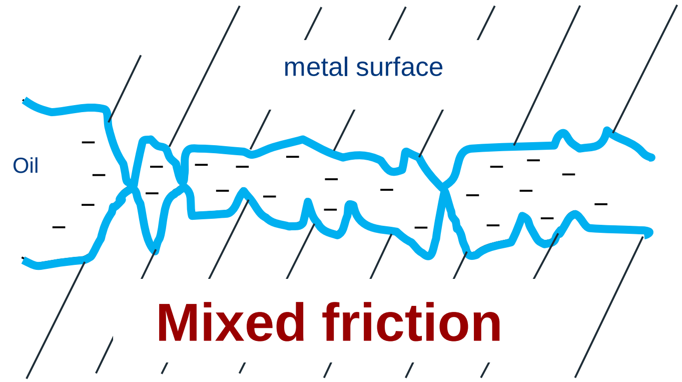
Why using anti-wear (AW) additives in CO_2 refrigeration oils ?

Anti-Wear (AW) additives are "activated" under mixed friction conditions :

→ Lubricating film tears off, no hydro-dynamics

→ No separating oil: contact of roughness peaks of the metal surfaces

Danger of wear !



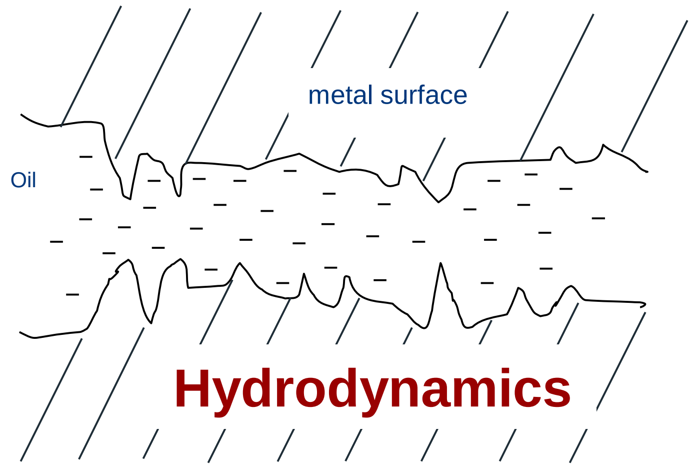
Mixed friction is more often present with CO_2:

High oil dilution with CO_2

High loads in the bearing

High temperature in lubricating gap

Low sliding speed (start-up)



AW additives form protective reaction layer on the surface

→ Protection against wear

Refrigeration oils for CO_2

Additional reactant carbonic acid

Carbonic acid: carbon dioxide and water

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$ carbonic <u>acid</u>

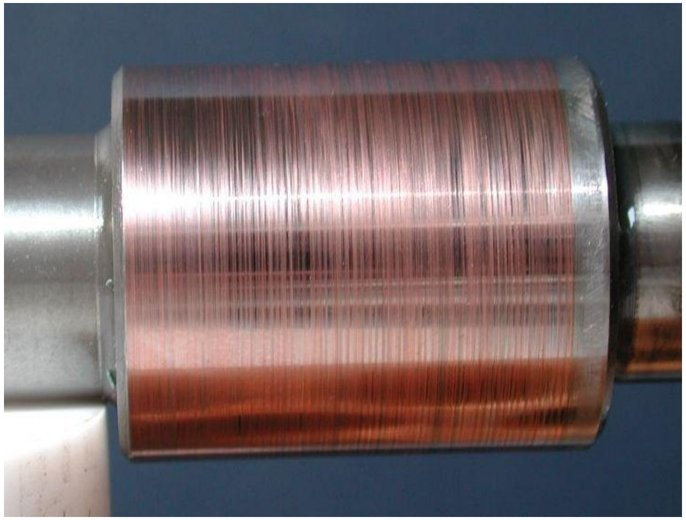
Possible consequences:

- Decomposition of the lubricant
- Attack of seals and metal surfaces→ corrosion, copper plating

Refrigeration oils for CO_2
Copper plating

Example: polyol ester oil (POE) with a water content of 300 ppm in CO_2 cascade system

Copper in polyol ester oil shows green colour (in some cases)



Copper plating main bearing of crank shaft

Summary / Outlook

- The number of applications using natural refrigerants is increasing
- New challenges for refrigeration oils – very specific & related to the refrigerant
- Lubricant solution do already exist and work
- But – there is still a lot more to learn and sometimes to improve

„Keep cool…it‘s all natural!“

Thank you for your attention!

eurammon is always available as a sparring partner for questions on refrigeration with natural refrigerants

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