Refrigeration Oils for Future Mobile A/C Systems

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FUCHS EUROPE Schmierstoffe
Alternative vehicle air conditioning ...

or

...using alternative refrigerants
Low GWP refrigerant successors for R134a (GWP = 1300)

... two candidates remain:

- **HFO-1234yf**  GWP = 3-6
  
  Use with conventional R134a components. Only minor adjustments necessary. Open questions: flammability (HF)

- **R744 (CO₂)**  GWP = 1
  
  high pressure level requires new components → high costs. Benefits: high vol. cooling capacity, not flammable, impact on human health is completely investigated, cheap

... new synthetic refrigeration oils necessary!
Refrigeration oil requirements in the cooling circuit

- High refrigerant miscibility:
  - oil transport back to the compressor
  - heat transfer
- Stability –
  - CO₂ transcritical → high temperature
  - HFO1234yf → reactivity
- Lubricating properties
- Low water content
- Material compatibility (elastomers)
Refrigeration Oils for CO$_2$
Different MAC applications – different lubricant types

**Bus**

- Reciprocating piston compressor
  - Polyol ester (POE, additivated)  
    - excellent CO$_2$ miscibility

**Passenger car**

- Axial piston compressor - open (belt drive)
  - Polylalkylene glycol  
    - compatibility with existing R134a oils (under investigation)

- Axial piston compressor - hermetic (hybrid / electric vehicle)
  - Polyol ester  
    - high electric resistance / good insulation properties
Refrigeration Oils for CO\textsubscript{2}  
RENISO ACC 46

→ refrigeration oil for open CO\textsubscript{2} compressors for passenger car a/c systems

• completely newly-developed PAG type as base fluid
• chemically-modified, double-endcapped PAG ISO VG 46
• additive package for enhanced wear protection and ageing & thermal stability
• experience from car fleet tests
• patent-protected formulation
Refrigeration Oils for CO₂
Miscibility behaviour of PAG / CO₂

Miscibility diagram (miscibility gap) PAG / CO₂

PAG / CO₂ has restricted miscibility properties

But:
RENISO ACC 46 is miscible in the conc. 1-3% oil in CO₂

→ safe oil transport in passenger car a/c systems
= compact systems

Miscibility diagram of RENISO ACC 46 / CO₂
Refrigeration Oils for CO₂
Thermal stability

Standard test conditions: storing at
220°C / 2 weeks / 50 bar CO₂

Oil analysis in order to detect a decomposition which is indicated by a change in
- neutralization number
- viscosity
- chemical structure (IR analysis)

Only special PAG / POE derivatives fulfill the requirements
Conventional R134a-PAG are not useful
Refrigeration Oils for CO₂
Thermal stability – oil after ageing: 2 weeks / 220°C / 50bar CO₂

c(H₂O) < 100 ppm

increase neutralization no. / TAN [mg KOH/g]

conventional R134a PAG

+ 1,48

8,2 %

decrease viscosity @ 40°C

→ less ageing with
RENISO ACC 46

(PAG for CO₂)

+ 0,47

0,6 %
Bearing fatigue lifetime test with axial roller bearings (AXK 18x35) under 50 bar CO₂ pressure

- testing of different refrigeration oil formulations
- the longer the bearing lifetime the better the wear protection of the tested oil
Refrigeration Oils for CO₂
Lubrication properties - CO₂ high-pressure bearing test rig

Test conditions: 140°C / 50 bar CO₂ / axial load 8 kN / 800 min⁻¹

- conventional R134a PAG: 37 hours
- RENISO ACC 46: 75 hours

→ RENISO ACC 46 doubles the bearing lifetime

(PAG for CO2)
Mixed friction:
Lubricating film is torn apart
- contact of roughness peaks
- no fluid friction (no hydro-dynamics)
- impact: wear

causes:
- high oil dilution with CO$_2$
- high loads in the bearing
- high temperature in lubricating gap
- on / off mode

Antiwear additives form protective reaction layer on the surface
→ Protection against wear
Refrigeration Oils for HFO-1234yf: Requirements & solution

Oil requirements:

- Good refrigerant miscibility properties
- Reliable lubrication properties
- High stability in combination with HFO-1234yf

Oil solution:

POE or PAG …?
Refrigeration Oils for HFO-1234yf: Miscibility Behaviour

PAG / HFO 1234yf has inferior miscibility behaviour compared to PAG / R134a

→ Special PAG structures are miscible with HFO-1234yf up to 30°C, POE up to 67°C

→ Is the performance of PAG sufficient for the situation in the condenser?
Refrigeration Oils for HFO-1234yf: Chemical Stability

Sealed Tube Test acc. ASHRAE 97/1999

Test conditions:
30% HFO-1234yf / 70% oil / 175°C / 500h / Fe + Al + Cu metal coupons

Comparison:
FUCHS base fluid ↔ additivated products

Increase in Neutralisation No. (Total Acid Number) in mgKOH/g (fresh oils: < 0,1)

<table>
<thead>
<tr>
<th>Water content [ppm]</th>
<th>PAG base oil</th>
<th>PAG add.</th>
<th>POE base oil</th>
<th>POE add.</th>
</tr>
</thead>
<tbody>
<tr>
<td>dry - PAG &lt;250 ppm / POE &lt;50 ppm</td>
<td>0,50</td>
<td>0,28</td>
<td>0,36</td>
<td>&lt; 0,1</td>
</tr>
<tr>
<td>wet - PAG 800 ppm / POE 300 ppm</td>
<td>0,95</td>
<td>0,48</td>
<td>0,60</td>
<td>&lt; 0,1</td>
</tr>
</tbody>
</table>

→ Additivation reduces the TAN significantly
→ POE exhibits lower acid values: higher stability

FUCHS additivation:
- stabilizer system
- anti wear additive

Comparison:
conventional PAG / R134
- < 0,1
- 0,5
Refrigeration Oils for Future Mobile A/C Systems: Conclusion

- **CO₂**: The necessary requirements for the refrigeration oil - adequate refrigerant miscibility, high thermal stability and enhanced wear protection (at mixed friction conditions) – can be fulfilled with newly developed PAG-based refrigeration oils that contain an effective antiwear and antioxidant additive system.

- **HFO-1234yf**: PAG and POE lubricants exhibit different refrigerant miscibility behaviour. POE has a smaller miscibility gap than PAG. The chemical stability of both systems POE and PAG can be improved by choosing a suitable stabilizing additivation of the refrigeration oil. The lubrication properties of PAG / HFO-12234yf are currently under investigation.
Thank you for your attention!

Questions welcome …!
Refrigeration Oils for CO$_2$
RENISO ACC 46

pVT diagram (Daniel Plot): RENISO ACC 46 / CO$_2$