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High Performance Polyalkylene Glycol Lubricants for CO₂ based air-conditioning / refrigeration systems.
Common Uncapped PAGs - Air-conditioning (Auto HFC)

Water Insoluble:

(R - most commonly Me, Bu)

\[
\begin{align*}
\text{Homo-polymer} \\
\text{Random Co-polymer}
\end{align*}
\]

(Terminating Hydroxide)

Water Soluble:

(R - most commonly Me, Bu)

(Terminating Hydroxide)

Random Co-polymer
Common Capped PAGs - Air-conditioning (Auto HFC)

“Symetrically” capped PAGs:

Homo-polymer

Random Co-polymer

(Most commonly terminating R = Initiating R, as both ends simultaneously capped)
Common Capped PAGs - Refrigeration / Air-conditioning (HFC)

“Asymetrically” capped PAGs:

Homo-polymer

(Terminating Group - hydroxyl)

(Terminating Alkyl - commonly Me)

terminating $R \neq$ Initiating $R$, two stage manufacturing process)
Capping Summary

Method A - single stage

Method B - two stage
Performance advantages of asymmetrically capped PAGs

(compared with symmetrically capped PAGs and uncapped PAGs)

- Improved HFC miscibility
- Enhanced Extreme Pressure / Antiwear properties
Symetric and asymmetric capped PAGs - R134a miscibility property.
Effect Of Capping On EP Characteristics Of PAGS

Modified Falex Test (R-134a atmosphere).
Modification of R / R' to enhance performance under conditions of CO$_2$ compressor:

- Enhanced CO$_2$ miscibility
- Enhanced Extreme Pressure / Antiwear property
- Stability under elevated temperature / pressure conditions
Asymmetric capped PAG - CO₂ miscibility property, (ISO 46 Grade)

Temperature (deg C)

Lubricant Content (Wt%)
Asymmetric capped PAG - CO$_2$ miscibility property.

No Low temperature CST

Density Inversion observed:

CO$_2$ rich solution

lubricant rich solution

REDUCING TEMP

CO$_2$ rich solution

lubricant rich solution
Asymmetric capped PAG - CO₂ miscibility property, (ISO 100 Grade)

Critical Solution Temperature

Density Inversion temperature

Lubricant Content (Wt%)
Asymetric capped PAG - CO$_2$ miscibility property.

- Miscibility with CO2 enhanced compared with uncapped and symmetrically capped PAGs.
- Viscosity reduction associated with miscibility minimal compared with POE.
- Lubricity property not disadvantaged by improved miscibility.
Asymmetric capped PAG - lubricating property in CO\textsubscript{2} systems.

Trans-critical CO\textsubscript{2} systems - higher load-bearing requirements.

Falex Block-on-Ring procedure:

- Load steps: 50lb steps, followed by 20lb steps
- Rotation: 600 rpm
- Atmosphere: CO\textsubscript{2}
- Overpressure: 10 bar (150psi)
- Step duration: 5 minutes
- Temperature: 90ºC minimum
- Ring / Block: Steel
Symetric capped PAG - lubricating property in CO₂ systems.
Asymetric capped PAG - lubricating property in CO₂ systems.
Asymmetric capped PAG (+EP/AW) - lubricating property in CO₂ systems.
Capped PAGs - lubricating property in CO\textsubscript{2} systems.

Falex Block-on-Ring Summary:

![Bar chart showing failure load for different test samples.]

- **Test sample A190**
- **Test sample A182**
- **Test sample A183**
Symetric capped PAG - lubricating property in CO\textsubscript{2} systems - Block wear.

A190
\textit{(Symetric capped)}

A182
\textit{(Asymmetric capped)}

A183
\textit{(Asymmetric capped +EP/AW)}

50lb load steps

50lb load steps

50lb load steps

20lb load steps

20lb load steps

20lb load steps
Capped PAGs - thermal stability in CO$_2$ systems.

Modified IP 48:

- CO$_2$ environment: (1 atmos pressure)
- CO$_2$ flow rate through sample: 15 litre/hr
- Temperature: 200ºC
- Time: 18 hours

Graph showing:
- Uncapped PAG
- Symmetrically capped
- Asymmetrically capped
Conclusions

- Novel capping technology enables the synthesis of PAG type lubricants with improved CO$_2$ miscibility, lubricity and thermal stability properties, of particular interest for CO$_2$ compressor applications.

- A flexible “capping” process can be utilised to allow structure modification and hence performance optimisation for the future refrigerant technology developments.