GEOlube® RFL Range
Product Data

GEOlube® RFL Range — TECHNICAL DATA SHEET

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Introduction

GEOlube® RFL grades are high performance novel polyalkylene glycol lubricants for CO_2 based air-conditioning / refrigeration systems.

Particular challenges and requirements exist when selecting lubricants for CO_2 based refrigeration systems.

GEOlube® RFL grades offer improved miscibility with CO_2 over a wide range of lubricant concentrations and temperatures. This results in excellent lubricity and increased efficiency of the refrigeration system.

GEOlube® RFL grades have reduced hygroscopicity compared with uncapped PAGs, which have a water absorbing tendency. They also offer high chemical, thermal and hydrolytic stability.

Refrigerant Overview

The refrigeration industry has undergone a number of changes due to the problems associated with ozone depletion and global warming. CFCs such as R12 and R115 were completely phased out in 2000. The phase out of HCFC's such as R22 began in 2010. HFC R134a then became widely used. However, this refrigerant is now being phased out in the automotive industry due to its high global warming potential (GWP).
No single refrigerant meets all of the requirements for the wide range of refrigeration applications. A number of alternative refrigerants have become established within the industry, including low GWP HFCs such as R1234yf and halogen-free refrigerants including NH_3 (R717), propane (R290), iso-butane (R600a) and carbon dioxide (R744).

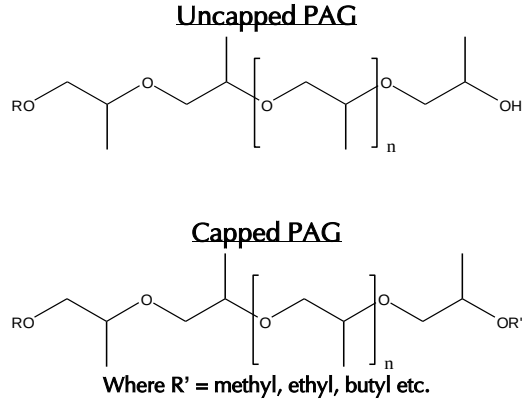
Carbon Dioxide Refrigerant

Carbon dioxide has no ozone depleting potential (ODP), negligible global warming potential (GWP), is non-flammable and chemically very stable. CO_2 is only harmful to health in very high concentrations and is inexpensive, hence eliminating any need for recovery and disposal. These safety characteristics were the main reason for the widespread use of CO_2.
CO_2 offers unfavourable characteristics for usual refrigeration applications, with a very high discharge pressure and a very low critical temperature of 31˚C (74 bars). This requires sub and supercritical operating conditions in single stage systems with discharge pressure above 100 bars, and in addition, the energy efficiency is lower compared to the traditional vapour compression process.
However, in applications with potentially high leakage rates and where flammable refrigerants cannot be accepted for safety reasons, there exist opportunities for CO_2. For instance, CO_2 continues to be a viable option for mobile air conditioning systems as well as in vehicle air-conditioning. For larger commercial and industrial refrigeration units, CO_2 may be used as a secondary fluid in a cascade system.

Capped PAG Technology

Performance advantages are associated with the use of **GEOlube® RFL** grades as synthetic lubricants for CO_2 refrigeration. A typical polyalkylene glycol generally consists of polymer chains with a terminating hydroxyl group at one end which is chemically active, whereas a "capped" PAG has chemically inactive groups at both ends of the molecule. **GEOlube® RFL** lubricants, based on "capped PAG" technology, provide efficient lubrication for compression type refrigeration units; improved lubricating properties for CO_2 systems are achieved as a result of the capping technology. High process efficiency typically results in ~95% capping for the **GEOlube® RFL** range. Performance advantages characterising the **GEOlube® RFL** range include:

- Miscibility with CO_2 over a wide range of lubricant concentration and temperature.
- Reduced hygroscopicity compared with water absorbing tendency of uncapped PAGs.
- High chemical, thermal and hydrolytic stability.
- Excellent lubricity.



Structural effect of capping on a typical α-alkyl-Ω-hydroxy-polyoxypropylene polymer

Product Range

ISO Grade	Formulated Product	Basefluid
46	RFL 46X	RFL 43
68	RFL 68X	RFL 65
100	RFL 100X	RFL 97

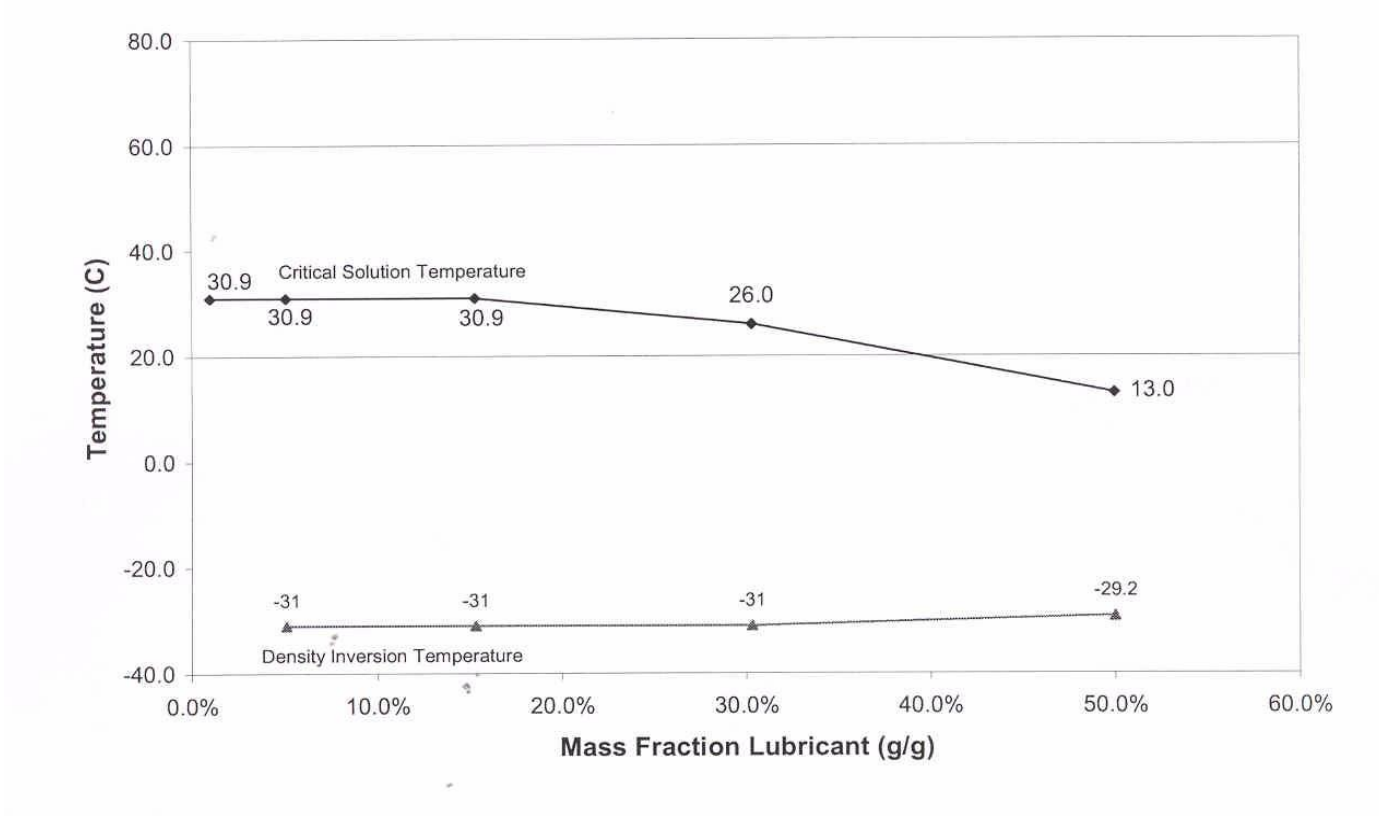
Typical Properties

Property	Method	RFL 46X	RFL 68X	RFL 100X
Viscosity@ 40°C, cSt	ASTM D445	**49.7**	**78.9**	**107.3**
Viscosity@ 100°C, cSt	ASTM D445	**10.7**	**15.7**	**20.0**
Viscosity Index	-	**213**	**213**	**216**
Density @ 20°C, kg/m^3	ASTM D1298	**998**	**998**	**999**
Pour point, °C	ASTM D97	**-49**	**-46**	**-43**
Flashpoint (COC), °C	ASTM D92	**>200**	**>200**	**>200**
Water Content, %mass	ASTM E284	**<0.05**	**<0.05**	**<0.05**
TAN, mgKOH/g	ASTM D974	**<0.10**	**<0.10**	**<0.10**
4-Ball wear scar -40kg/1hr (mm)	ASTM D4172	**0.53**	**0.52**	**0.58**
Cu corrosion test	ASTM D130	**1a**	**1a**	**1a**
Steam turbine corrosion test	ASTM D665(a)	**Pass**	**Pass**	**Pass**
Miscibility in CO2:				
Upper CST: 1% RFL-X in CO_2	ASHRAE 86	**30.9**	**-**	**30.9**
5% RFL-X in CO_2		**30.9**	**-**	**30.9**
30% RFL-X in CO_2		**26.0**	**-**	**27.0**
50% RFL-X in CO_2		**13.0**	**-**	**16.0**
Density Inversion temp: 1% RFL-X in CO_2		**-31.0**	**-**	**-32.0**
5% RFL-X in CO_2		**-31.0**	**-**	**-32.0**
30% RFL-X in CO_2		**-31.0**	**-**	**-32.0**
50% RFL-X in CO_2		**-29.2**	**-**	**-31.0**

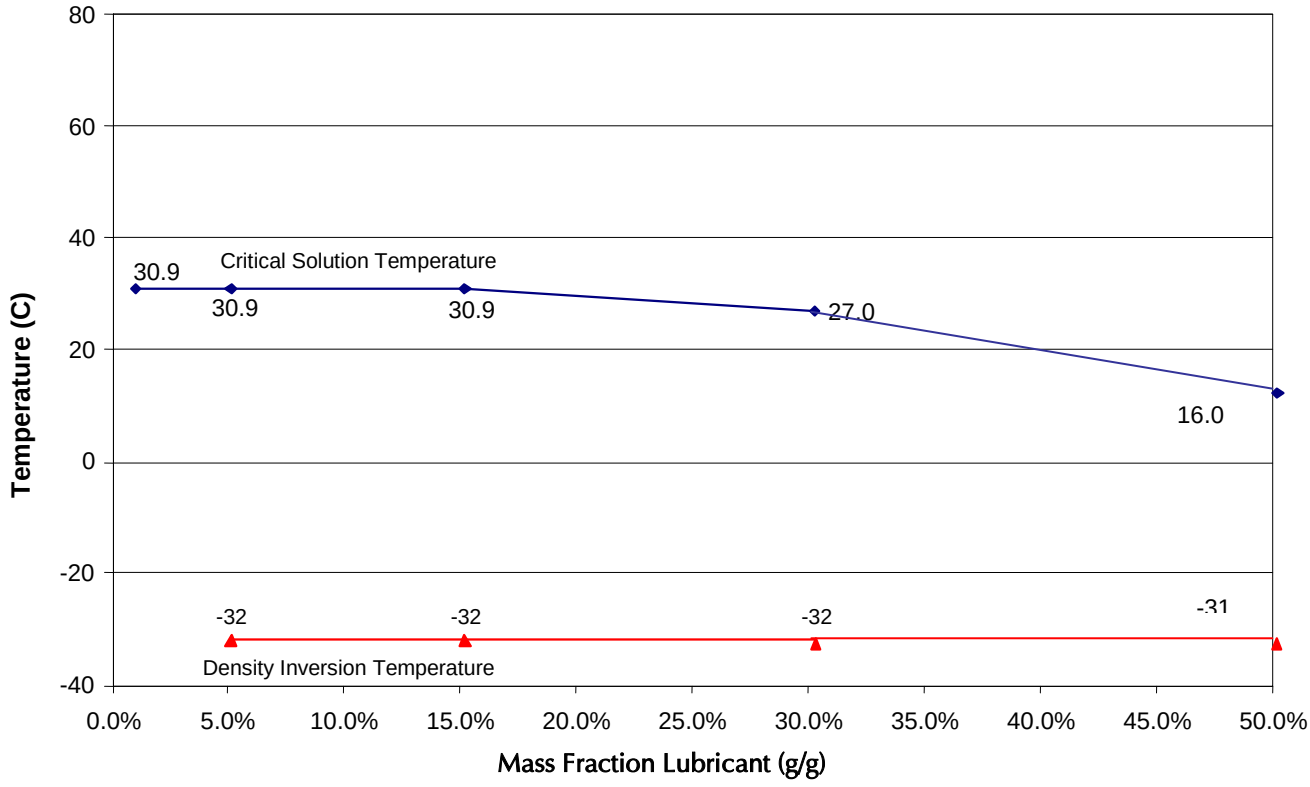
Miscibility above and below the Carbon Dioxide Critical Point (30.98°C)

The majority of conventional lubricants such as mineral oils and alkyl benzenes are not soluble with CO_2. Polyol ester (POE) synthetic lubricants show very good miscibility properties, however this can result in a dramatic reduction in viscosity in the refrigerant condenser. PAGs show partial miscibility with CO_2, however the viscometric properties of polyalkylene glycols remain unaffected and the decrease in viscosity observed with POEs is not observed for PAGs under CO_2 dilution. **GEOlube® RFL** grades show miscibility with CO_2 over a wide range of lubricant concentrations and temperature.

Miscibility of GEOlube® RFL 46X with CO_2



Miscibility of GEOlube® RFL 100X with CO_2



An upper critical solution temperature, consistent over a wide range of lubricant concentrations, is observed for the **GEOlube® RFL** grades. A low temperature critical solution temperature does not occur, although a density inversion in the liquid phases is observed over the full lubricant concentration range tested.

Critical Solution and Density Inversion Data for GEOlube® RFL 46X / CO_2

% Composition Lubricant	Critical Solution Temperature (°C)	Density Inversion Temperature (°C)
1.0	30.9	Suspended droplets
5.1	30.9	-31.0
15.3	30.9	-31.0
30.3	26.0	-31.0
50.0	13.0	-29.2

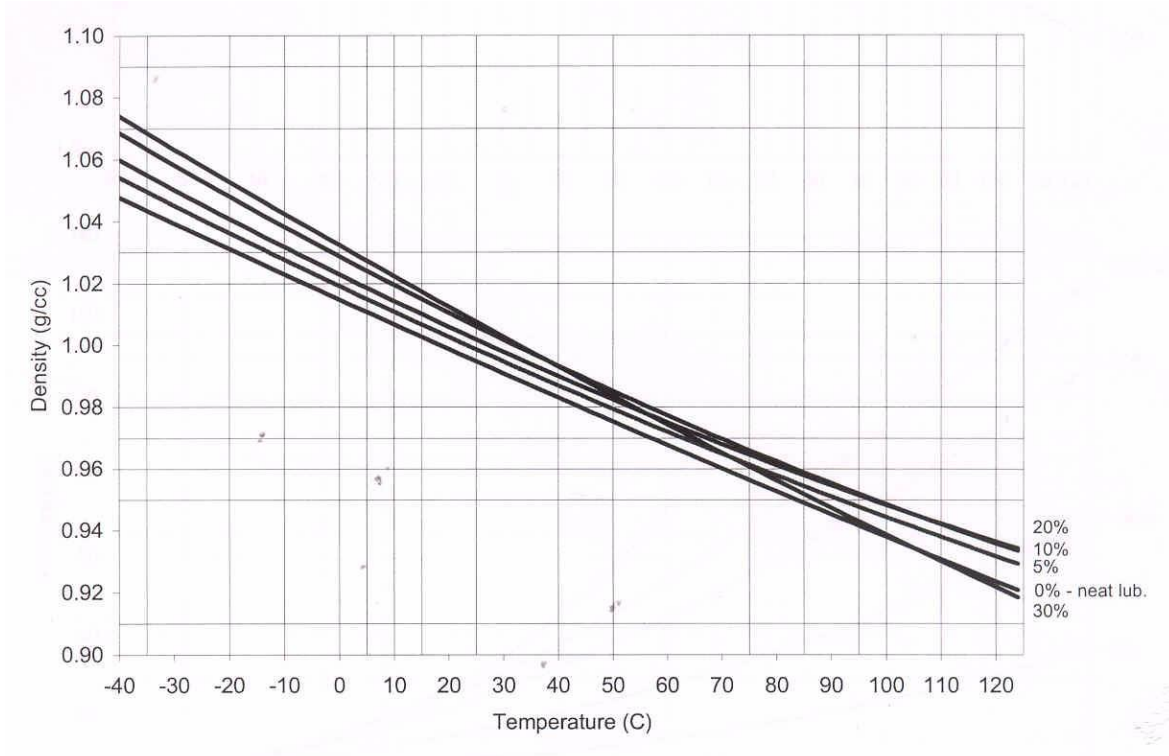
Critical Solution and Density Inversion Data for GEOlube® RFL 100X / CO_2

% Composition Lubricant	Critical Solution Temperature (°C)	Density Inversion Temperature (°C)
1.0	30.9	Suspended droplets
5.1	30.9	-32.0
15.2	30.9	-32.0
30.3	27.0	-32.0
50.0	16.0	-31.0

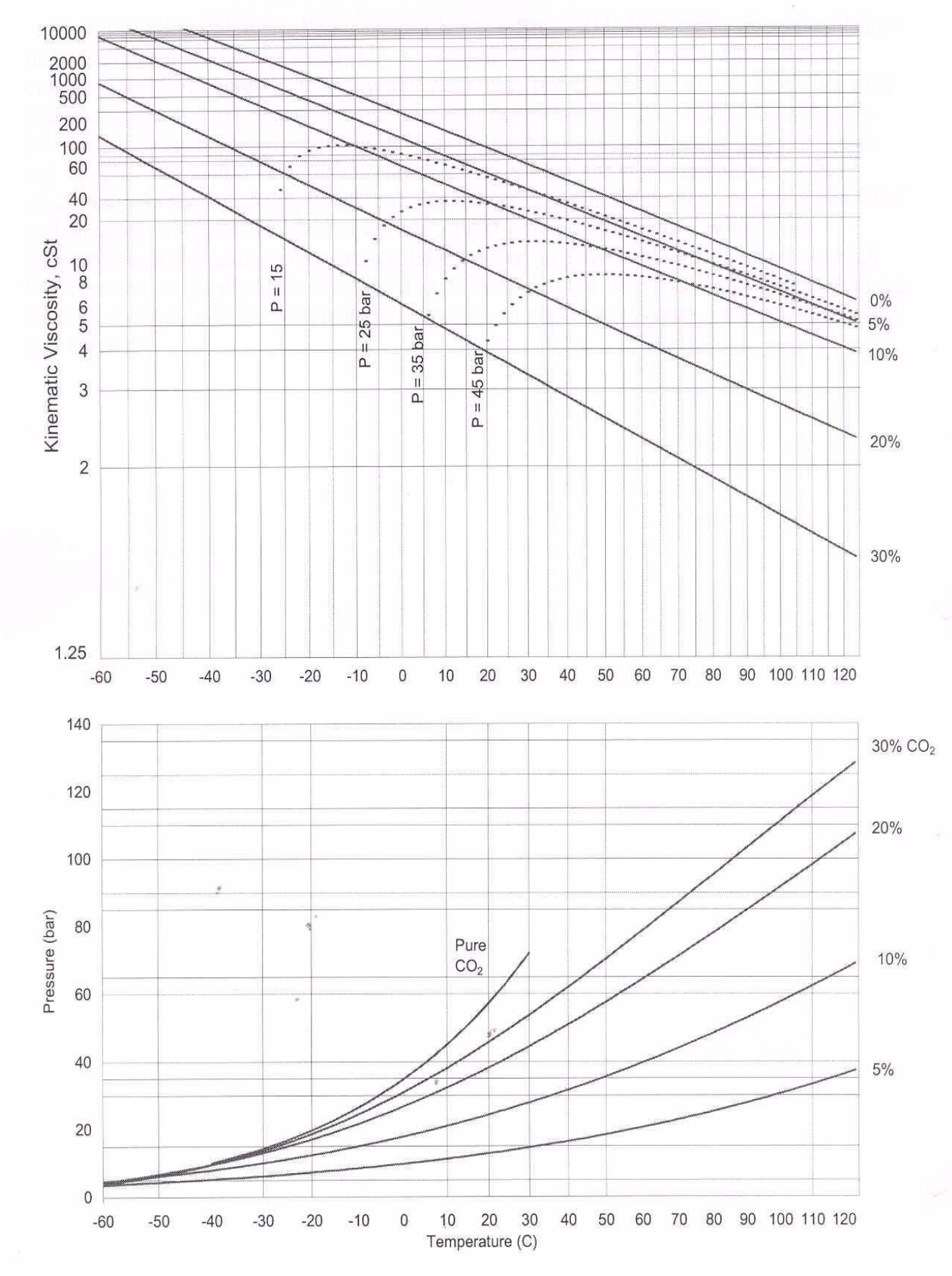
Solubility, Liquid Density and Liquid Viscosity of GEOlube® RFL 46X

Experimental measurements of liquid density, vapour pressure (solubility) and liquid viscosity have been recorded at **GEOlube RFL® 46X** concentrations of 70, 80, 90 and 95 wt%, over a temperature range of – 40°C to + 125°C.

Density of GEOlube® RFL 46X / CO_2



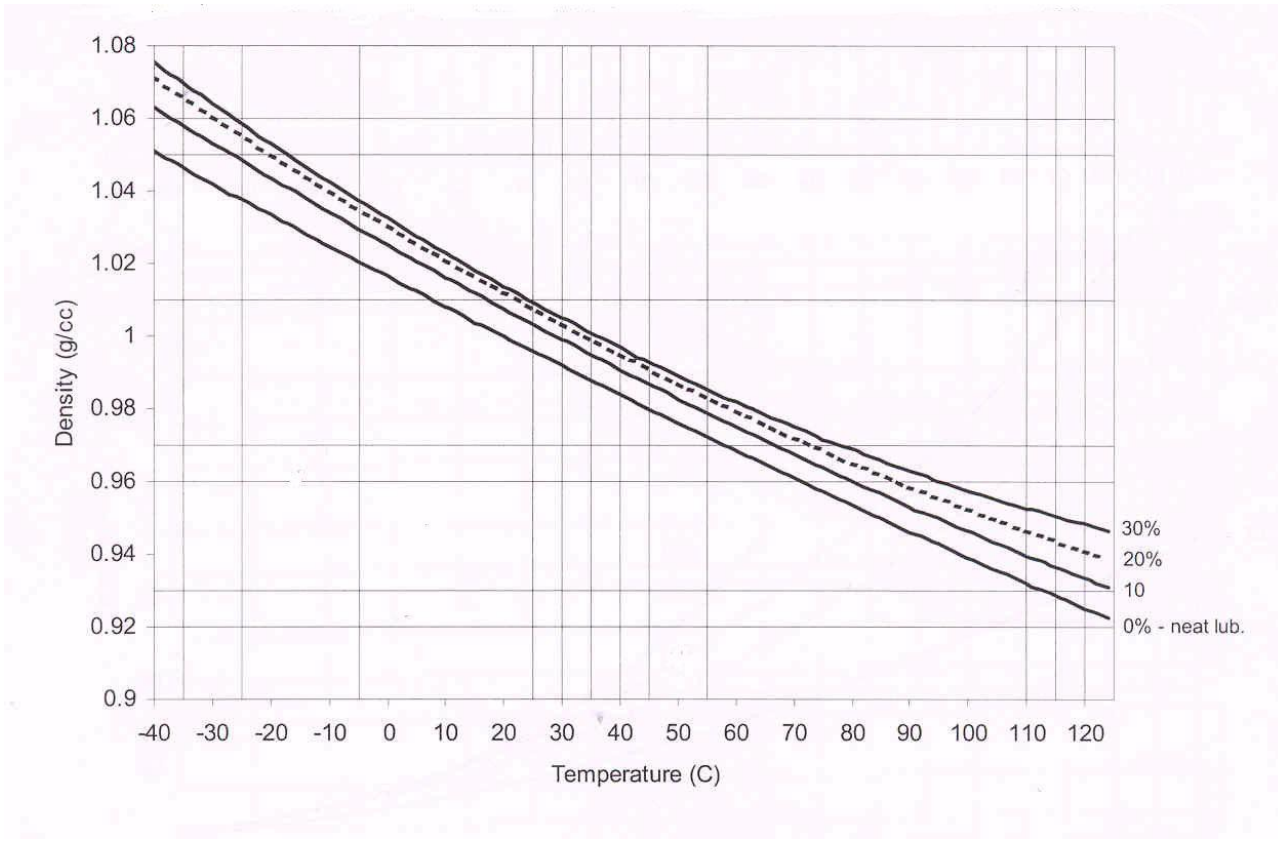
Viscosity and Vapour Pressure Data for GEOlube® RFL 46X / CO_2



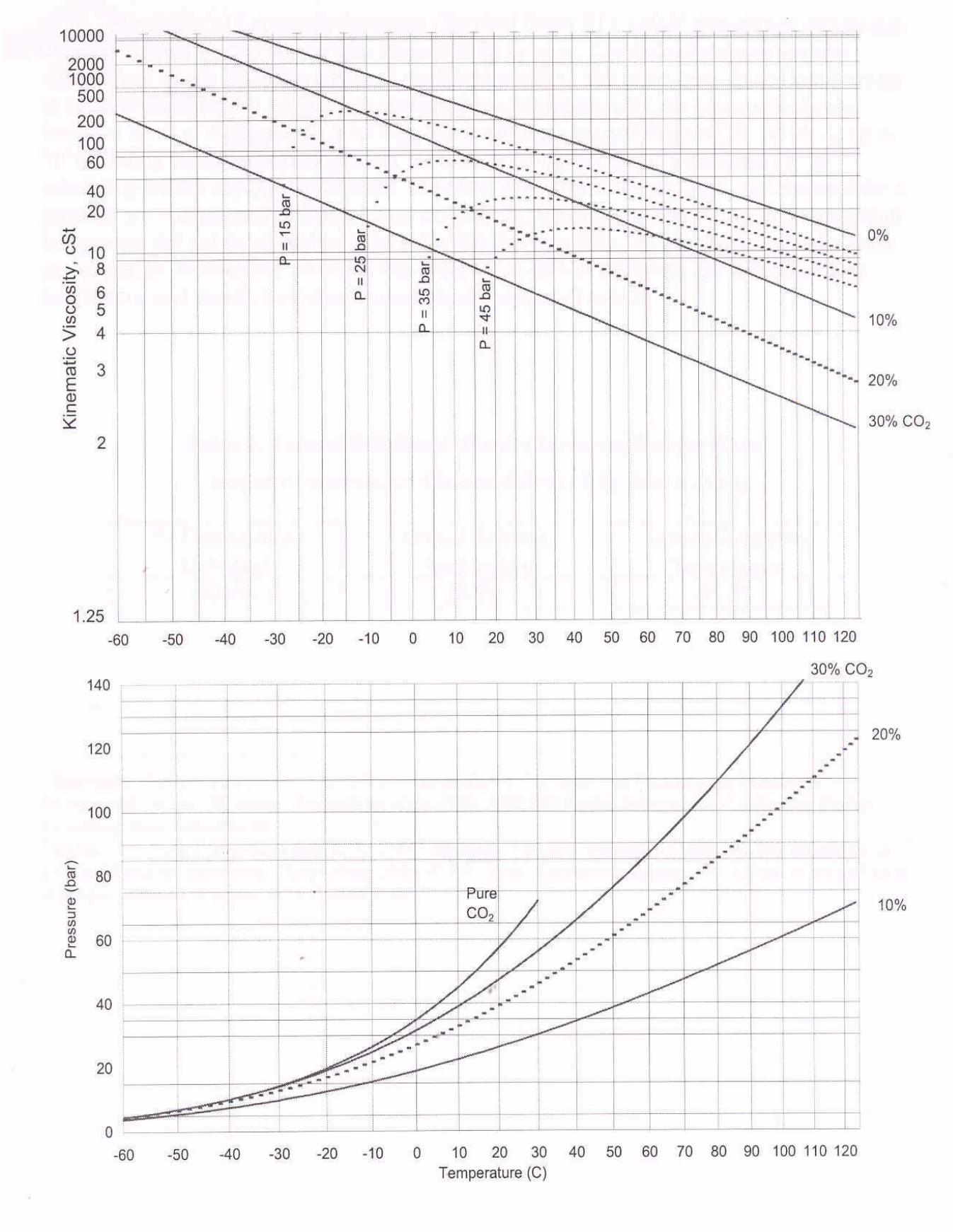
Solubility, Liquid Density and Liquid Viscosity of GEOlube® RFL 100X

Experimental measurements of liquid density, vapour pressure (solubility) and liquid viscosity have been recorded at **GEOlube® RFL 100X** concentrations of 70, 80, 90 and 100 wt%, over a temperature range of – 40°C to + 125°C.

Density of GEOlube® RFL 100X / CO_2



Viscosity and Vapour Pressure Data for GEOlube® RFL 100X / CO_2



Lubricity Properties

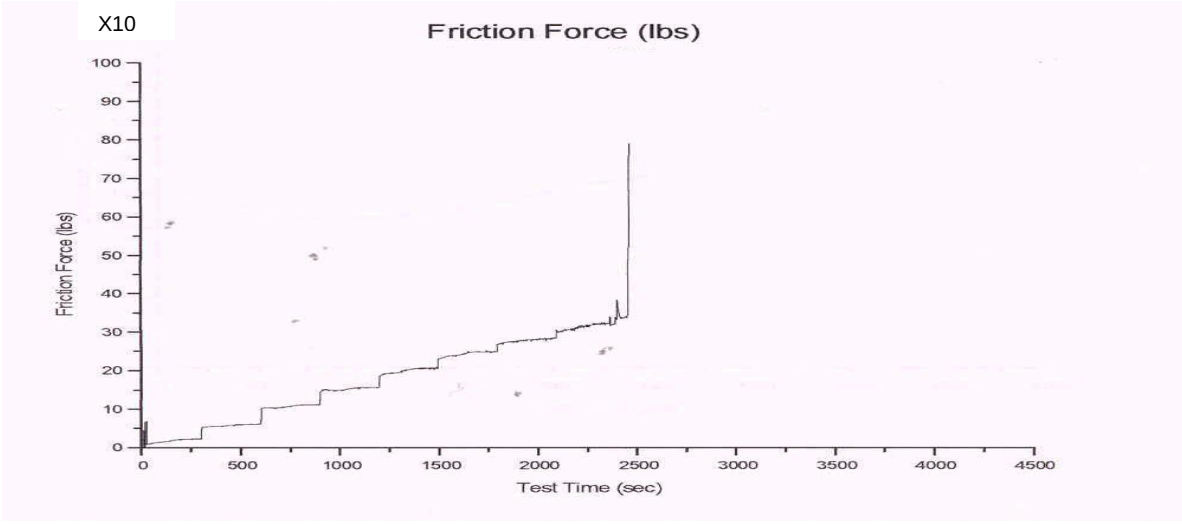
The development of trans-critical CO_2 systems requires speciality lubricants due to the high pressure and subsequently higher loading on bearings. The extreme pressure and anti-wear properties of PAGs are superior to POEs and other synthetics such as PVEs, with such lubricating properties being retained under high pressure CO_2 conditions. **GEOlube® RFL** lubricants, based on "capped PAG" technology, provide efficient lubrication for compression type refrigeration units, improved lubricating properties for CO_2 systems are achieved as a result of the capping technology.

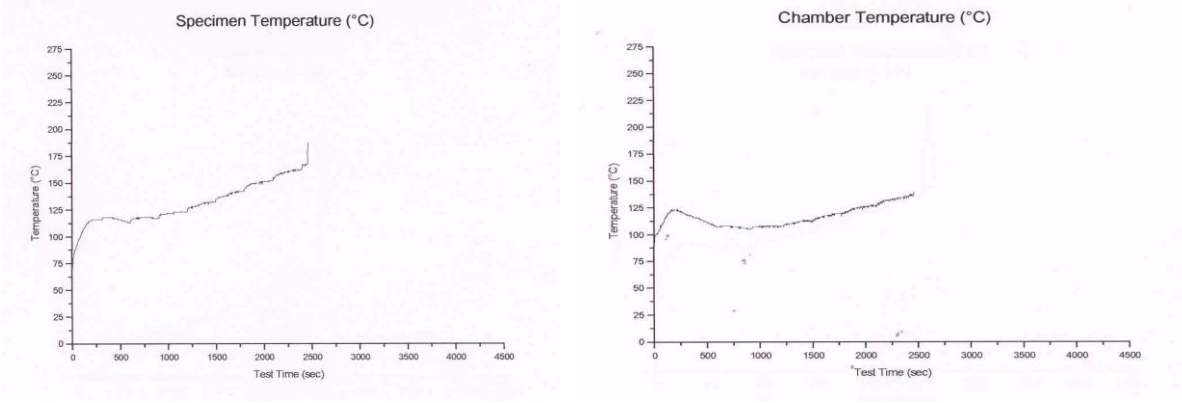
To simulate as accurately as possible the CO_2 pressurised environment, Falex Block-on-Ring testing has been used to assess the load carrying properties of the **GEOlube® RFL** grades using the following test parameters:

Load Steps	+50 lbs, followed by +20lbs
Rotation Speed	600 rpm
Atmosphere	CO_2
Overpressure	10 bar (150 psi)
Step Duration	5 minutes
Temperature	Min 90°C
Ring	Falex S10, SAE 4620 steel, Rc5 8-63 6-12 rms
Blocks	Falex H-30, SAE 01 steel, Rc 27-33, 4-8 rms

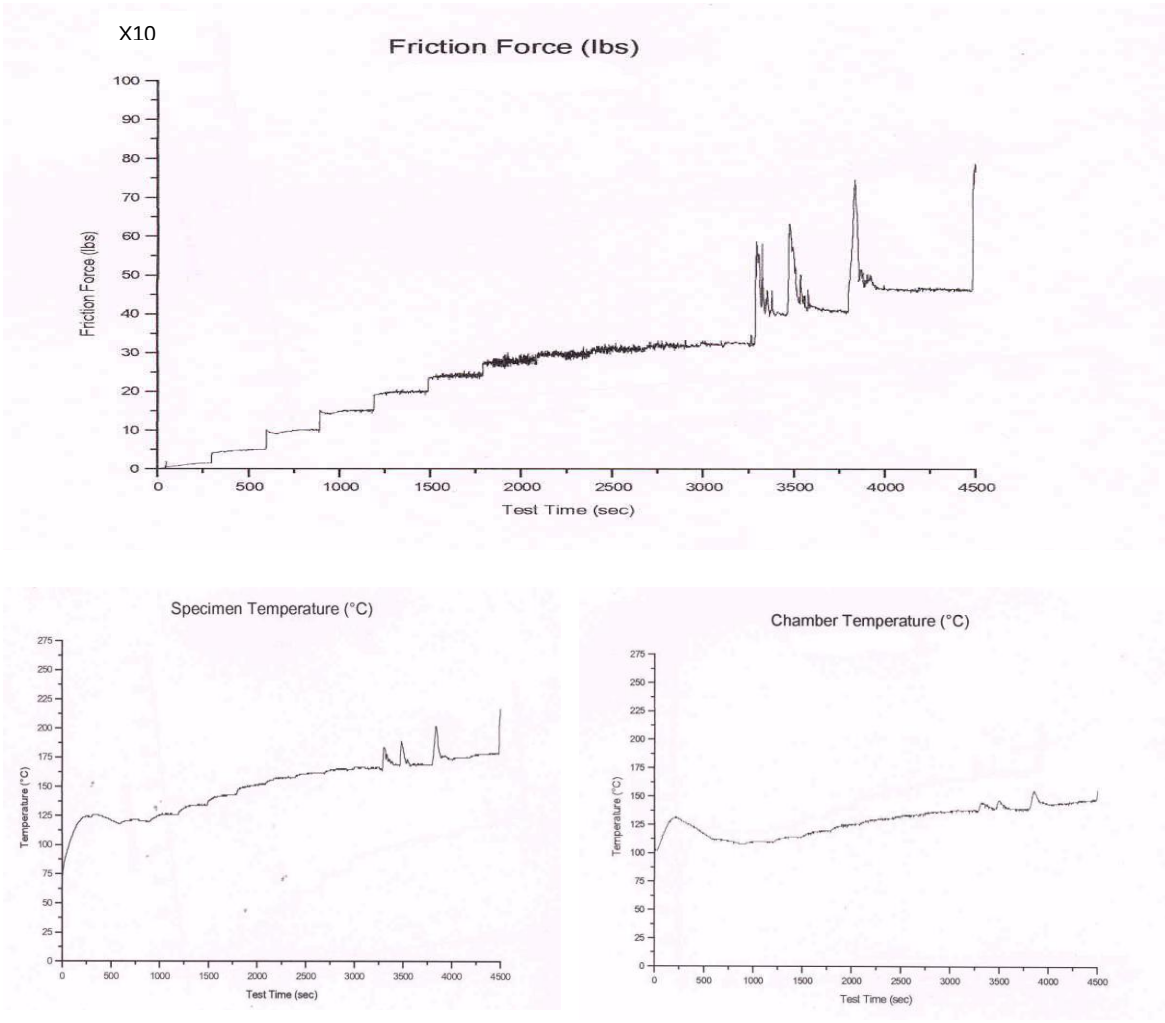
The Extreme Pressure Load (lbs) and Estimated Wear Scar (mm) were recorded for **GEOlube® RFL 46X** (and with additional EP/AW additisation – **GEOlube® RFL 46EP**):

With increasing steps of 50lbs:





With increasing steps of 20lbs:



Measured at increasing steps of 20lbs:

EP Load (lbs) – **GEOlube® RFL 46X**	380
EP Load (lbs) – **GEOlube® RFL 46EP**	420
Estimated Wear Scar before seizure (mm) – **GEOlube® RFL 46EP**	2.0

Hydrolytic Stability

Uncapped polyalkylene glycols are very hygroscopic and may absorb several thousand ppm of water when exposed to humid conditions, however despite this PAGs will not hydrolyse under typical operating conditions and therefore cannot result in problems typically associated with absorbed water in alternative synthetic lubricants such as polyol esters, such as corrosion of bearings or ice formation in the expansion valve / capillaries.

Due to the replacement of the terminal hydroxyl group by an alkyl species in the **GEOlube® RFL** grades, hygroscopicity is reduced below that of an uncapped PAG.

Water Absorption Properties of GEOlube® RFL grades

(Environment Relative Humidity 52%, temp. 20°C, sample size 30g, surface area 3.1cm², stirrer speed 500 rpm)

Whilst water absorbed by the PAG is not free (but bound to the PAG) and hence does not result in the problems which may be associated with free moisture, the reduced hygroscopicity exhibited by **GEOlube® RFL** grades ensures low requirements for the water content of a system can be achieved through a choice of capped PAG. A maximum water content of 0.05% water is defined for the **GEOlube® RFL** grades.

Health and Safety

A Safety Data Sheet (SDS) has been issued describing the health, safety and environmental characteristics of the **GEOlube® RFL** grades, together with advice on handling precautions and emergency procedures. This must be consulted and fully understood before storage, handling and use. Based on current information, **GEOlube® RFL** grades do not have adverse effects on health when handled and used properly.