1 LUBRICATING OILS FOR SCREW COMPRESSORS

1.1 Lubricating oil selection list

Special refrigeration oils must be used for Grasso screw compressors. The selection of the oils depends on the chemical properties of the oil, the refrigerants, the operating conditions of the plant and the required oil viscosity during start up and run. After inquiring with the compressor manufacturer, oils other than those listed in the table may also be used. Further information on listed oils, are given in the data sheets and diagrams of the oil manufacturer. For refrigeration compressors, special refrigeration oils have to be used. The selection depends on the refrigerant, viscosity (at least 7 cSt for oil temperature before entering the compressor), evaporating temperature (pour point) and requirement made of the oil separation behaviour (flash point, viscosity).

Basis of the lubricating oils and used abbreviations:

M **Mineral oil**

M* **Mineral oil with special treatment (hydrocracked oil)**

AB **Alkyl benzene**

PAO **Polyalphaolefin**

E **Polyolester**

PAG **Polyalkylenglycol**

"X"-"Y" **Mixed oil from previous base oils**

Table 1: Lubricating oils for R717 (ammonia)
(recommended especially if minimum oil carry-over from the oil separator is important)

Manufacturer	Type of oil	Basis	Viscosity at 40 deg. C in cSt	Flash point in deg. C	Pour point in deg. C	Remark	NSF grade [1)]
CPI	CPI 1009-68	M*	68	226	-40	Hydrotreated	H2
	CPI 1008-68	M*	64.9	240	-39		H2
Klüber Lubrication	Klüber Summit RHT 68	M*	68	240	-39		H2
	Klüber Summit R 100	PAO	32	> 230	-60		H1

Table 1: Lubricating oils for R717 (ammonia)
(recommended especially if minimum oil carry-over from the oil separator is important)

Manufacturer	Type of oil	Basis	Viscosity at 40 deg. C in cSt	Flash point in deg. C	Pour point in deg. C	Remark	NSF grade [1]
	Klüber Summit R 150		46	> 240	-51		H1
	Klüber Summit R 200		68	> 230	-45		H1
Shell	Shell Refrigeration Oil S2 FR-A68	M*	68	232	-39	Hydrotreated	
Petro-Canada	Reflo 68A	M*	58	236	-42		H2
TEXACO	Capella Premium	M*-PAO	67	262	-42		
Paramo	Mogul Komprimo ONC 68	M*	68	230	-33		
TOTAL	Lunaria NH 68	M*	68	230	-36		
Fuchs	Reniso Ultracool 68	M-PAO	62	250	-48		H2
NXT Next Lubricants	NXT-717 [1]	M*	60.6	249	-42		

[1] Application area in the food-processing industry according to NSF (**N**ational**S**anitation **F**oundation, www.nsf.org)

- H1: Applicable in all food-processing environments where there is the possibility of incidental food contact.
- H2: Applicable in all food-processing environments where there is no possibility of incidental food contact.

[2] Only the oil NXT-717 without suffix is approved for use in Grasso Screw compressors. The products NXT-717-SC and NXT 717-FG are specially treated oils and not approved for use in Grasso screw compressors.

Table (2): Lubricating oils for DX Chiller with R717 (ammonia)							
Manufac-turer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour point in deg. C**	**Remark**	**NSF grade [1)]**
CPI	CPI 412-100	PAG	98	226	-40		
Fuchs	Reniso PG 68	PAG	62	230	-35		
Mobil	Zerice S32	AB	32	154	-33	Please con-tact manufac-turer	

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Table 3: Lubricating oils for R717 (ammonia) and R22							
Manufac-turer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour point in deg. C**	**Remark**	**NSF grade [1)]**
Castrol	Aircol 299	M	56	180	-34	for R22 only	
	Aircol AMX 68	M	28	260	-30	for R717 only	
	Aircol 2294	PAO	69	233	-60	for R717 only	
CPI	CPI 4600-46F	PAO	46	268	-42	for R717 only	H1
MOBIL	Zerice S32	AB	32	154	-33		
	Zerice S68	AB	68	174	-27		
	Gargoyle Arctic SHC 226E	PAO	68	266	-45	for R717 only	H1
	Gargoyle Arctic SHC NH 68	AB-PAO	64	211	-54		
	Gargoyle Arctic 300	M	68	200	-42		
	Gargoyle Arctic C Heavy	M	46	195	-42		
Fuchs	Reniso S68	AB	68	190	-33		
	Reniso Synth 68	PAO	68	260	-57	for R717 only	H1
	Reniso KS 46	M	46	195	-42		

Table 3: Lubricating oils for R717 (ammonia) and R22							
Manufac-turer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour point in deg. C**	**Remark**	**NSF grade [1)]**
	Reniso KC 68	M	68	200	-39		H2
Shell	Shell Refrigera-tion Oil S4 FR-V 46	AB	46	180	-42		
	Shell Refrigera-tion Oil S4 FR-V 68	AB	68	190	-39		
TOTAL	Lunaria NH 46	M	46	226	-36	for R717 only	
	Lunaria SH 46	PAO	44	252	-51	for R717 only	H1
	Lunaria FR 68	M	68	175	-34	for R22 only	
Petro-Can-ada	Reflo Synthetic 68A	AB-PAO	62	245	-54	for R717 only	

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Table 4: Lubricating oils for R134a; R404A; R407C; R410A; R507							
Manufac-turer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour point in deg. C**	**Remark**	**NSF grade [1)]**
Castrol	Aircol SW 68	E	68	245	-39		
	Aircol SW 220		220	250	-27		
CPI	Solest 68	E	64	266	-43		
	Solest 120		125	262	-27		
	Solest 220		216	271	-27		
Fuchs	Reniso Triton SE 55	E	53	270	-51		H2
	Reniso Triton SEZ 80		80	275	-39		
	Reniso Triton SEZ 100		91	288	-39		
	Reniso Triton SE 170		170	260	-24		
	Reniso PAG 220	PAG	220	240	-38	for R134a only	
Shell	Shell Refrigera-tion Oil S4 FR-F 68	E	66	230	-42		
	Shell Refrigera-tion Oil S4 FR-F 100		94	230	-42		

Table 4: Lubricating oils for R134a; R404A; R407C; R410A; R507							
Manufac-turer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour point in deg. C**	**Remark**	**NSF grade [1)]**
MOBIL	EAL Arctic 68	E	68	230	-36		
	EAL Arctic 100		105	250	-30		
TOTAL	Planetelf ACD 100FY	E	100	270	-30		
	Planetelf ACD 150FY		150	272	-36		

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- H2: Applicable in all food-processing environments where there is no possibility of incidental food contact.

Hint!

When using high-viscosity oils with high refrigerant solubility after initial fill of the plant a sufficient mixture from refrigerant and oil has to be provided before start-up the screw compressor.

Table 5: Lubricating oils for natural gas and hydrocarbon compounds							
Manufacturer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour-point in deg. C**	**Remark**	**NSF grade 1)**
Castrol	PD 68	M	68	234	-21	for natural gas compression	
CPI	CPI 1515-68	PAG	65	224		For heavy hydrocarbons, where strong dilution or condensation will occur	
	CPI 1515-100		103	260			
	CPI 1516-68		62	229		For propane refrigerant plants or volatile hydrocarbons, where the danger of stronger dilution or condensation does not exist	
	CPI 1516-100		92	260			
	CPI 1516-150		153	260	-34		
	CPI 4600-68	PAO	60	271		For high temperature application and for feed gas control compressors for gas turbines	H2
	CPI 4600-100		106	271			H2
	CPI 9001-68	M	69	241		for feed gas control compressors for gas turbines	
	CPI 9001-100		108	260			H2
	CPI 1507-68	PAG	62	231		For heavy hydrocarbons, for hydrocarbon cooling applications in range of high pressure/ low temperature	
	CPI 1507-100		89	260			
MOBIL	Glygoyle 11	PAG	85	226	-45	For natural gas and propane	
	Glygoyle 22		177	229	-41		

Table 5: Lubricating oils for natural gas and hydrocarbon compounds							
Manufacturer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour-point in deg. C**	**Remark**	**NSF grade [1)]**
Shell	Corena S3 R68	M	68	240		For natural gas	
	Shell Gas Compressor Oil S4 PV 190	PAG	190	262	-30	For natural gas and propane	
TOTAL	DACNIS LPG 150 [2)]	PAG	142	280	-48	For natural gas, propane and volatile hydrocarbons	
Klüber Lubrication	Summit NGSH-100	PAO-E	140	250	-46	For natural gas, for feed gas control compressors for gas turbines and hydrocarbons	

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- H2: Applicable in all food-processing environments where there is no possibility of incidental food contact.

[2)] Product re-branded from "TOTAL Primera LPG 150" into "TOTAL DACNIS LPG 150".

Table 6: Lubricating oils for CO_2-application							
Manufac-turer	**Type of oil**	**Basis**	**Viscosity at 40 deg. C in cSt**	**Flash point in deg. C**	**Pour point in deg. C**	**Remark**	**NSF Grade[1)]**
CPI	CPI 4624-46F	PAO	46				H1
	CPI 4624-68F		68				H1
Fuchs	Reniso C 85 E	E*		278	-42	complete miscible	H2
	Reniso C 130 E	E*	136		-27		
	Reniso C 170 E	E*	170		-30	attend to the miscibil-ity gap	
Klüber Lubrication	Klüber Summit R 200	PAO	68	> 230	-45		H1

* During application of ester oils: $t_{oil\ inlet} \leq t_{discharge} - 4K$

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Hint!

When using high-viscosity oils with high refrigerant solubility after initial fill of the plant a sufficient mixture from refrigerant and oil has to be provided before start-up the screw compressor.

Table (7): Use of O-ring elastomer in screw compressors depends on refrigerant and lubricant:								
Refrigerant	**Oil**							
	M	**M***	**M*-PAO**	**AB**	**E**	**PAO**	**AB-PAO**	**PAG**
R717 (ammonia)	CR/ HNBR	CR/ HNBR	CR/ HNBR	CR	-	HNBR CR *)	CR	CR/ HNBR
R22	CR	-	-	CR	CR	-	CR	-
R134a, R404A, R407C, R410A, R507, R23	-	-	-	-	HNBR	-	-	-
R290 (propane), R1270 (propylene)	-	-	-	-	-	HNBR	-	HNBR
R744 (Carbon dioxide CO_2)	-	-	-	-	CR	HNBR	-	CR

*) only for oils:

- Fuchs Reniso Synth 68
- Klüber Summit R100/ R150/ R200

Abbreviations used for the elastomers:
CR Chloroprene (Neoprene rubber)
HNBR Hydrogenated nitrile butadiene caoutchouc

Hint!

If natural gas and hydrocarbon compounds are used as compression medium (Table (5);Page 8), O-ring elastomer should be requested from the manufacturer depending on the operation condition.

Hint!

- The pour point describes the cold fluidity of an oil and represents a non-guaranteed benchmark value for the minimum evaporating temperature. [The pour point is defined as the temperature at which the fluidity of an oil decreases to an extent that it does not leave a jar within 5 sec under certain conditions.]
- Compressors are equipped with suitable elastomers at the sealing point, which are selected dependent on the refrigerant and lubricant. (Table (7); Page 11)
- When selecting the type of oil, the compatibility of the sealant material used in the compressor for o-rings (elastomer quality) must be taken into consideration in addition to the refrigerant. (Table (7); Page 11)
- Not all the listed oil types can be used for an existing compressor. It is absolutely necessary to assign the oil grade depending on the elastomer used, even if the refrigerant is the same.
- Oil grades are not always compatible with each other (cannot be mixed).
- Changing from one oil type to another can lead to disruptions in the operation of the compressor and to leakages at the sealing points. The compressor manufacturer should always be contacted before changing the oil type.

Caution!

- **The specified range of viscosity of the lubricating oil upstream of the compressor has to be observed in any case. At the same time, it must be noted that refrigerant/oil combinations are possible in which, dependent on the pressure and temperature in the oil separator of the package, the refrigerant dissolves in the oil. This leads to a reduction of the viscosity of the pure oil and to the formation of foam when the solution equilibrium is altered due to pressure reduction or temperature increase. In this case, the oil must be cooled by a minimum temperature difference, which is calculated in the compressor selection programme for the given operating conditions. The compressor may only be operated if the oil entry temperature is complied with in accordance with the compressor selection programme!**
- **The oil separation behaviour of the types of oil given in the Table can vary greatly (e.g. influence of oil vapour pressure, oil viscosity, solubility, final compression temperature).**

1.2 HINTS FOR SELECTION OF REFRIGERATION OIL

The characteristics of refrigerating machine oil influence the functionality of a refrigerator with oil flooded screw compressors, since this cannot be precluded despite the high-capacity oil separator and remnants of refrigerating machine oil can enter the refrigerant line. So when selecting oil,

- a sufficient lubricity of the oil at the bearing points of the screw compressor (minimum oil viscosity with consideration of the solubility of refrigerants in oil depending on both the pressure and temperature),
- the vapour pressure of the oil for a proper separation behaviour in the oil separator,
- a sufficient fluidity of the oil at both the evaporating and suction temperature,
- the requirements upon the miscibility of the liquid phases of the refrigerant and the oil (miscibility gap).

need to be taken into account.

The refrigerant used, the operation conditions and the specific plant design all determine the required characteristics of the refrigeration oil.

At present, five different base oil brands are used:

1. Mineral oils for ammonia and R22
2. Polyalphaolefins for ammonia and CO_2 (R744)
3. Alkyl benzene for ammonia and R22
4. Polyglycol (PAG-oil) for ammonia, CO_2 and R134a
5. Ester oil for R 404A, R 134a, R 507 and CO_2 as well as other refrigerant blends such as R410A and R407C

Besides the pure base oil components other blends of mineral oil and alkyl benzene or of polyalphaolefin and alkyl benzene can also be used.

The characteristics of the refrigerants regarding the oils mentioned are very different.

Thereby 2 fundamental requirements are needed from the refrigerant and refrigeration oil:

a) Minimum oil viscosity of 7 cSt, maximum 70cSt, at the compressor inlet with consideration for the refrigerant solubility in oil

and

b) Miscibility of both liquid phases of a certain portion of the oil (ab. 1 to 2 %) and the refrigerant.

In addition to the lubrication oil viscosity requirements the discharge temperatures in the compressor need to be high enough so that oil containing refrigerants can be cooled by at least 10 K, so that no foam forms in the compressor in the event of lower temperatures and/or temperature increases before the oil reaches the storage locations. The basic requirements b) are not fulfilled by mineral oil, alkyl benzine polyalphaolefin in association with ammonia, since the no 100% mixture gap is created and neither the solubility of the refrigerant vapour in the oil nor miscibility in the liquid phases. Nevertheless these oils are used NH_3 plants. Fine oil separation phases prevent larger oil volumes from entering the refrigeration circuit.

The base oil versions mentioned will bring about differing oil carry-over rates as the flash points of the oils cited differ greatly from each other (lowest flash point of alkyl benzene at approx. 160 °C, highest flash point of polyalphaolefin considerably above 200 °C).

Although the fluidity of the oil is characterized by the pour point indicated by the oil manufacturers, the basic oil types named above have varying VT characteristics so that even with equivalent initial viscosities such as 68 cST viscosity differences may occur at lower temperatures in the evaporator, which at -20°C vary between 1500 and 20000 cSt.

With relation to oils, the refrigerants feature the following properties:

- ***Ammonia***

  With the exception of PAG oil, ammonia is not soluble with other lubricants. The mechanical mixture is very intense so that oil is always carried with the ammonia. Due to the low share of ammonia, the lubrication of the oil will not change and the miscibility of oil and refrigerant during the liquid phases is not possible. Efficient oil separation is thus necessary.

- ***HFC (e.g. R134a, R404A, R507)***

  HFC contains no chlorine and is not limited in its applications. Ester oil is used for this refrigerant. The greater solubility of this refrigerant in ester oil needs to be taken into account when selecting an oil, since the initial viscosity of the oil through the dissolving of refrigerant in the oil can change significantly. However, the fluidity of the oil in the evaporator is given due to proper miscibility over a wide range.

The most important properties of the main oil groups are described in the following:

1. ***Mineral oil***

   Naphten-based mineral oils are best suited for refrigerating plants, but paraffin-based oils are also used. Special treatment (paraffin removal) means that paraffin-based oils have more or less the same characteristics as naphten-based oils. Mineral oils are characterised by relatively low miscibility with HCFCs (e. g. R22) at lower temperatures. Mineral oils have a relatively high viscosity index and low steam pressure (high flammability) that positively influences the oil impact.

2. ***Alkyl benzene (also known as alkyl benzole)***

   Alkyl benzenes are synthetic oils created from natural gas. They are characterized by high miscibility with HCFC's (e.g. R22) even at lower evaporating temperatures. Alkyl benzenes have greater thermal stability than mineral oils (ammonia use in piston compressors). However they have a higher tendency towards foam formation than mineral oils in the oil separator and thus to greater discharge despite the lower flame point. When switching from mineral oil to alkyl benzenes, it should be noted that alkyl benzenes have higher cleaning efficiency and thus the filter will dirty faster after the oil change.

3. ***Polyalphaolefin***

   Polyalphaolefins are synthetic oils with high levels of chemical and thermal stability. They are thus preferred for use in compressors with high discharge temperatures e. g. in heat pumps Polyalphaolefins are also used in ammonia plants. The very low pour point creates a very low evaporating temperature. The high flame point leads to low oil discharge.

   The high aniline point of polyalphaolefin causes a relatively high shrinkage of O-rings with CR material whereby leakages may occur even at static seals, when mineral oils or alkyl benzenes are replaced by polyalphaolefins.

   Shrinkage can be avoided if synthetic oil mixtures of polyalphaolefin and alkyl benzine are used. For use of pure PAO oils, Grasso compressors will be equipped with HNBR rings where no shrinking associated with the oil can occur.

4. ***Ester oils***

   As opposed to mineral oils, alkyl benzines and polyalphaolefins, ester oils are soluble in the new non-chlorinated HFC's (R134a, R404A, R507 etc.) So ester oils are thus the only lubricant that may be used with HFCs. Ester oils have a high flash point, whereby the oil vapour share in the oil separator and thus the oil discharge are positively influenced. Ester oils are hygroscopic. They absorb water when they come into contact with the atmosphere. Ester oils thus need to be stored in sealed containers. The compressors needs to be thoroughly evacuated before the oil filling.

5. ***Polyglycol oil***

   Polygylcol oils are soluble in ammonia and very hygroscopic. They are thus subject to the same handling conditions as ester oils. When selecting oils the drop in viscosity resulting from dissolving refrigerants in the oil needs to be taken into consideration. The flowablility of the oil in the evaporator needs to be tested taking into account the miscibility between the refrigerating machine oil and the refrigerant at each relevant evaporating temperature.

PARAMETERS USED FOR OILS:

Specific density

The density difference between the coolant and oil may be important for the oil return. Care should be taken that alkyl benzine has a lower density than mineral oils and polyglycol and greater density than mineral oil. The methods for measuring density is described in DIN 51757.

Viscosity

In accordance with the ISO 3448 standard lubricants are classified according to viscosity classes listed as ISO VG No . The ISO No. is only a nominal value in such classes, i. e. the actual viscosity may deviate in certain areas (DIN 51562). The viscosity entries are based on the temperatures of 40°C and 100°C.

Viscosity index

The viscosity index supplies the connection between the change in viscosity depending on the temperature (ISO 2909). Greater viscosity index readings mean lower viscosity changes when temperatures change compared to lower viscosity index values.

Flash point

The flash point indicates at which temperature the vapours escaping from a heated cup may be ignited over a flame. The measuring method is described in ISO 2592. Oils with higher flash points have lower oil vapour pressures. This will enhance the possibilities of oil separation from a compressed gas in the oil separator and reduce the oil carry-over rate from the compressor into the plant.

Pourpoint

The pour point is the temperature, where the flowability of oil declines so that that under certain conditions no oil will flow from a container within five seconds. In accordance with the standards, the pourpoint temperature is 3% lower than the measured temperature (measuring method in accordance with ISO 3016) The pour point is interesting for material pairs that are not soluble with one another. Oils with a low pourpoint are easier to lead back to the suction side than oils with higher pour points. Practice teaches that it is possible to use oils at evaporating temperatures lower than the pourpoint without having any operational problems.

Floc point

The floc point is the temperature where R12 liquids with a 10% oil admixture will become darkened due to wax particles separating from the oil when the liquid is cooled (measuring method in accordance with DIN 51351). The floc point is interesting when oils and refrigerants are mixed together. The floc point displays that an oil has fewer wax components and plants with HCFC (e. g. R22) can be operated at lower evaporating temperatures. Wax from oil can lead to problems on the expansion valves or on regulating valves. A critical solution temperature shall be supplied for ester oils using a mixture of 10% oil and 90% R134a. The critical solution temperature is that which the oil is completely removed from the refrigerant (no standardized amount).

Aniline point

The aniline point indicates the temperature at which a homogeneous solution will clear when warmed with a constant volume share of a lubricant or lubrication material or oil and aniline when cooling and clouding occurs through separation upon cooling. The aniline point is the measurement of unsaturated carbon which can be found in the oil. It is also the measurement of various sealing materials the oil comes into contact with (measuring method in accordance with ISO 3977). Most refrigerating machine oils have a low aniline point. Neoprene or chloroprene o-rings swell and therefore need to be replaced after disassembly. Polyalphaolefin refrigerating machine oils have a high aniline point so the neoprene will shrink. When using polyalphaolefin as refrigerating machine oil the use of HNBR as material in the o-rings is necessary.

Neutralization number

The neutralization number displays the acidic value of an oil and is generated using titration with caustic soda (KOH). The value is provided in mg KOH per g oil (measurement method in accordance with DIN 51558). Fresh oil should have low neutralization number.

Hints for oil change

When changing the oil type or the manufacturer of an oil, consult the seal manufacturer beforehand to prevent any problems in operating the plant. If the oils are not compatible excretions from the oil are possible which may lead to problems with the plant (oil filter, lubricating capacity of the bearings, oil return not assured). Should it still be necessary to use another type of oil it is absolutely imperative that all oil be removed from the plant and compressor and oil separator be thoroughly cleaned (when possible with additional rinse cycle).

Oil selection table

All oils permitted for use in Grasso screw compressors are listed in the oil selection table. Depending on the specifications of the plant the technical characteristics listed above need to be taken into consideration when making the oil selection.