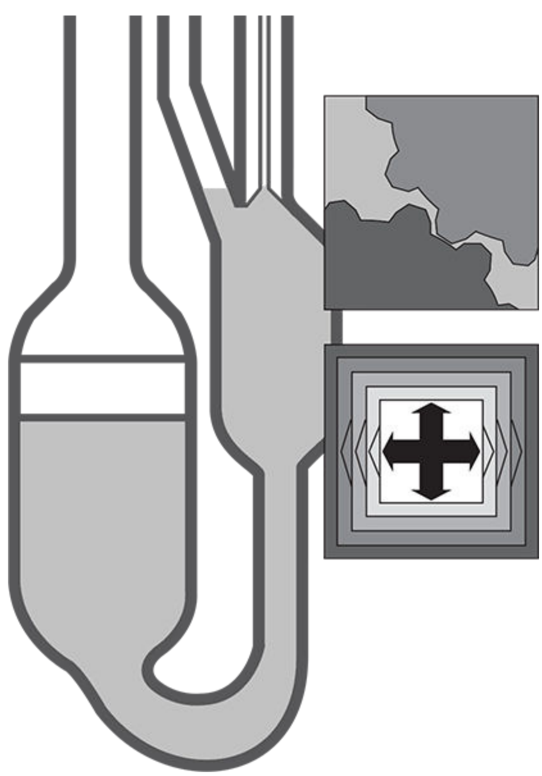
ENGINEERING
TOMORROW

Danfoss

Technical Information

Hydraulic Fluids and Lubricants
Oils, Lubricants, Grease, Jelly



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Revision history

Table of revisions

Date	Changed	Rev
July 2016	Major update. Updated for Engineering Tomorrow.	0801
November 2015	Minor text change.	0703
Mar 2014	Converted to Danfoss layout – DITA CMS	HD
Oct 2002	New Edition	AA

Contents

General Information

Disclaimer

Any warranty applicable for failures related to components of Danfoss Power Solutions does not apply for any fluid related damages, unless such warranty has been expressly and specifically granted.

The rated data which is published in this Technical Information and Service Manuals is based on the use of premium lubricants containing oxidation, rust and foam inhibitors.

Caution

It is not permissible to mix lubricants, different additive packages may cause negative interactions. If lubricant mixing cannot be avoided, fluid manufacturer's approval is required.

Introduction

The purpose of this manual is to aid the machine operator in the selection of suitable hydraulic fluid, gear lubricants, gear bearing grease, preservation fluid and petroleum jelly.

The specifications of the lubricant manufacturer and the recommendations of the machine manufacturer are the basis for selection and subject to change without advance advice. The choice of suitable hydraulic fluids or lubricants is critical for the lifetime, operational safety and efficiency of hydrostatic components and gears.

If there are any fire hazards, see instructions in *Health, accident and environmental measures* on page 4.

The selection of the appropriate hydraulic fluid or gear lubricant for a specific application can be made only when the different features of the lubricants and the task and conditions under which the machine is to operate are taken into consideration. Content subject to change.

Health, accident and environmental measures

When operating units, which are filled with hydraulic fluids, gear lubricants, grease or preservation fluids (hereafter referred to as lubricants) the operator must consider, among other things, the following precautionary measures:

- Prolonged skin contact with the lubricants is to be avoided. Careful skin cleansing of sticky fluid and regular changing of with lubricant soiled work clothes is required.
- Skin contact with fluid or with heated unit parts is to be avoided, especially at temperatures over 60 °C [140 °F].
- Should lubricant get into your eyes, rinse them thoroughly with tap water and see a doctor if necessary.
- Official regulations must be observed when storing lubricants (e. g. fire extinguishers, emergency exits).
- If there are any fire hazards, the use of fire resistant fluids is recommended.
- Clean up spills to avoid slipping (e. g. normal commercial cleaning agents).
- Lubricants must not seep into the ground or get into the sewer system.
- Concrete floors as foundations can be protected against fluids by being sealed or being painted with fluid-resistant paint.
- The first time start up of systems filled with hydraulic fluid, all unnecessary personnel has to stay away from the system.
- Old or unusable fluids are to be collected. Quantities above 200 liters [53 US gal] are presently picked up free of charge in Germany by the authorized collectors, as long as prohibited foreign substances are not added to these.
- For safety reasons, the flash point of the hydraulic fluid should always be at least 20 °C [68 °F] above the maximum fluid working temperature.
- Current official regulations must be observed.

General Information

API Classes of the base oil

Fully formulated hydraulic fluids consist of a blend of a base fluid and an additive package. These base fluids are categorized by the American Petroleum Institute (API) into five groups – API 1509, Appendix E. The differentiation between them bases on the refining method, amount of saturates, viscosity and percentage of sulfur. Only groups I to III are products from the refinement of a petroleum crude.

Due to different manufacturing processes, these fluids show different content of saturates and different viscosity indices (VI). Group I to III fluids can include some VI-improvers, which result in higher VI. Group IV and V represent synthetic fluids. Thereby group IV includes polyalphaolefines (PAO) and group V all residual fluids, which do not fit into the group I-IV as example biodegradable HEES, HETG and HEPR.

Base oils specification

Oil type	Mineral base oils			Synthetic base oils	
Group	**I**	**II**	**III**	**IV**[1)]	**V**
Saturates	< 90%	> 90%	> 90%	100%	All other fluids, including HEES, HEPG, HEPR
Viscosity Index	80-120	80-120	> 120	> 135	
Sulfur	> 0,03%	< 0,03%	< 0,03%	—	
Manufacturing Process	Solvent refined	Hydrothreated	Hydrocracked	Synthesized	
Polarity	high	low	unpolar	low	often high

[1)] Group IV - polyalphaolefines

Hydraulic fluid features

Hydraulic fluids have the primary purpose of transferring potential or kinetic energy (pressure and movements), create volume flow between pump and hydrostatic motor, and reduce the wear of parts that rub against each other. In addition, they protect the system from corrosion and help carry away the heat produced during energy transformation.

The following tables give an outline of the requirements for hydraulic fluids:

Necessary characteristics of hydraulic fluid

Required	Prerequisites
Volume stability	adequate capacity to separate air
Wear protection capacity	for a hydrodynamic or hydrostatic fluid layer between sliding surfaces
	adequate viscosity at operating temperature
	for all others wear reducing additives
Corrosion protection capacity	non–aggressive toward customary materials and rust protection additives

Desirable characteristics of hydraulic fluid

Desirable	Prerequisites
Only slight change in usage	adequate oxidation resistance
	for some cases of application adequate deemulsification capacity
	adequate shear stability, if polymer viscosity index improvers are used
Viscosity–temperature behavior	so that oil changes due to summer and winter operation become redundant
	adequate Viscosity–Temperature behaviour
Interaction with seals / gaskets	standard sealing materials can be used
	minimal characteristics changes of standard elastomers

For most of the identifying characteristics listed in the table, there already exist standards or at least preferred testing procedures which allow a numerical classification of these identifying features.

General Information

Hydraulic fluid has to perform the following tasks:

- Energy transmission
- Lubrication
- Heat removal

When choosing a hydraulic fluid the following features are most important for consideration:

- Viscosity
- Viscosity Index (VI) and/or Viscosity Grade (VG) viscosity at 40 °C [104 °F].
- Pour point
- Shear stability, when polymer VI-improvers are used

For any application the features of the hydraulic fluid must be appropriate to the operating environment of the unit and its components.

The fundamental features of the hydraulic fluids are described below.

Viscosity

A hydraulic fluid has a low viscosity when it is thin and a high viscosity when it is thick. The viscosity changes with the temperature.

- If the temperature increases, viscosity is reduced.
- If the temperature decreases, viscosity is increased.

Hydraulic units work under extreme temperature changes, especially in heavy duty vehicles. The viscosity range of the hydraulic fluid is extremely important.

The hydraulic fluid must be thin enough to flow through the filter, inlet and return pipes without too much resistance.

On the other hand, the hydraulic fluid must not be too thin, in order to avoid wear due to lack of lubrication and to keep internal leakage within limits.

In the hydraulic business typically the **kinematic viscosity 'ν'** in mm^2/s [SUS] is used for calculations, mainly for calculating the pressure drop in the connecting hoses and pipes.

The other measure is the **dynamic viscosity 'η'** in mPa•s. Dynamic viscosity is used for calculating the lubricating film thickness in a journal bearing and similar sliding films between adjacent parts.

Conversion of viscosities:

Dynamic viscosity (η) = kinematic viscosity (ν) x density (ρ): $\boldsymbol{\eta = \nu \cdot \rho}$ (mPa•s)

General Information

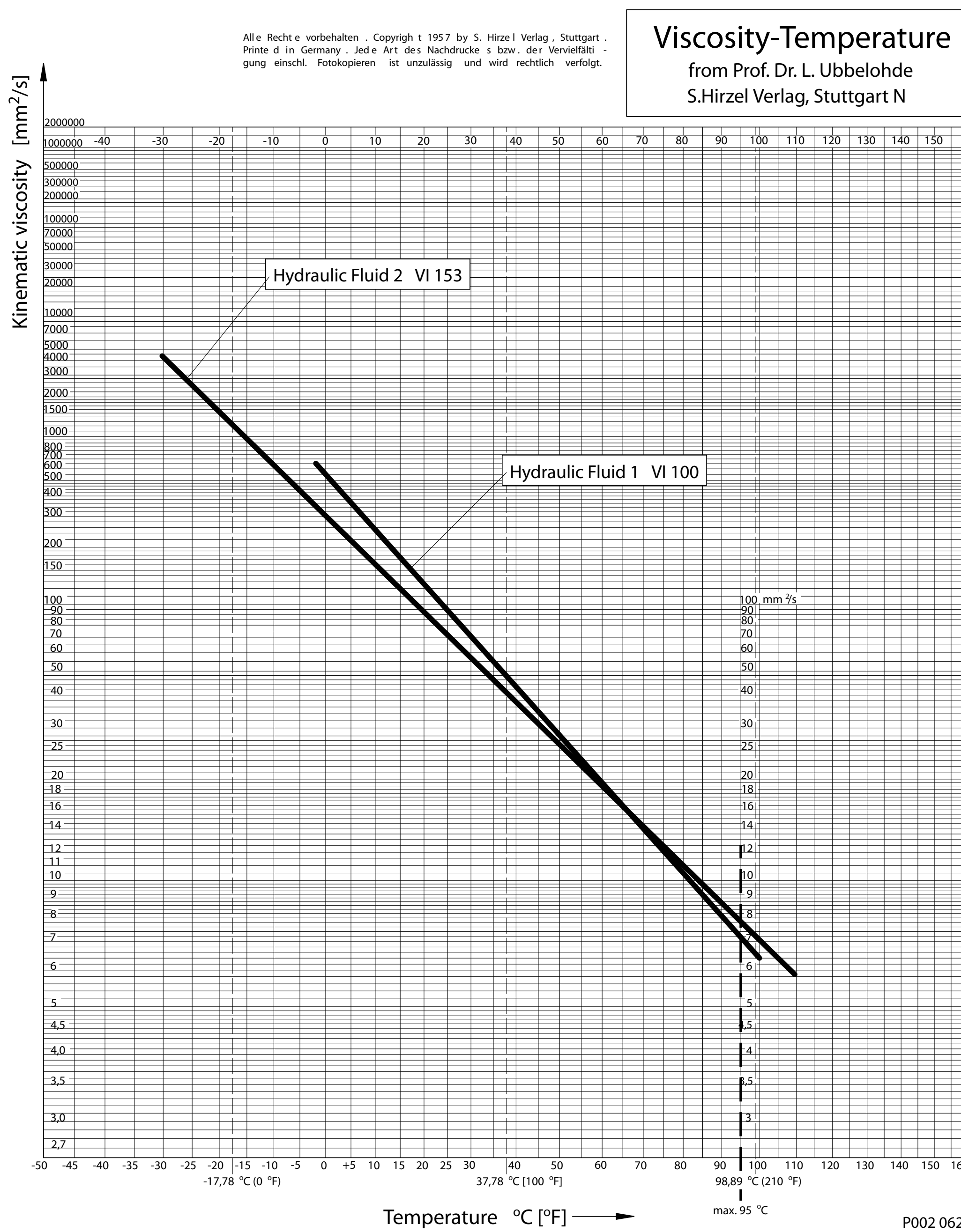
Viscosity index (VI)

The viscosity index is a calculated number according to DIN ISO 2909, which describes the viscosity change of a mineral oil based or a synthetic fluid in dependence of temperature.

- a **high** viscosity index means a **small** viscosity change when the temperature changes
- a **low** index means a **large** viscosity change when the temperature changes

Viscosity – temperature diagram according to Ubbelohde representing the temperature operating range of hydraulic fluids with different viscosity index (VI).

Viscosity – Temperature diagram from Prof. Dr. Ubbelohde



Standard mineral oil based (Group I and Group II) hydraulic fluids have a VI value of 90 – 110.

General Information

Hydraulic fluids with a VI larger than 110, e.g. between 130 – 200, are not as sensitive to temperature change. These hydraulic fluids distinguish themselves by starting up well and having minimal loss in performance at low temperatures. At high temperatures a sufficient sealing effect and protection against wear is achieved by using hydraulic fluids with high viscosity index. The high durability of a hydraulic fluid with a high viscosity index avoids damage and machine breakdown, lowers the operating cost and increases the life of hydrostatic transmissions and units.

Shear stability

Fluids using polymer viscosity index improver may noticeably shear down (> 20 %) in service. This will lower the viscosity at higher temperatures below the originally specified value. The lowest expected viscosity must be used when selecting fluids. Consult your fluid supplier for details on viscosity shear down.

Pour point

The pour point according to ISO 3016 defines the temperature when the fluids stops to flow. Start up temperature is recommended to be approximately 15 °C [59 °F] above hydraulic fluid pour point.

Density

The density has to be specified by the manufacturer of the hydraulic fluid. Using hydraulic fluid with a high density requires the sufficient diameter of the suction line and/or elevated tank to provide positive inlet pressure.

Examples for density at 15 °C [59 °F]

Hydraulic fluid type	Density at 15 °C [59 °F]
Petroleum (mineral) based fluids	0.86 — 0.90 g/ml
Syntetic ester	0.92 — 0.926 g/ml
Rape seed oil	0.92 g/ml
Water	1.00 g/ml
Polyalkylenglykol	1.02 g/ml
HFC	1.08 g/ml
Polyethylenglykol	1.10 g/ml
HFD (phosphate ester)	1.13 g/ml

General Information

Sealing compatibility

The procedure for testing the compatibility of the seal material is described in ISO 6072. In general NBR (Nitrile) or FPM (Fluorocarbon, Viton) is used as seal material for static and dynamic seals. For most hydraulic fluids both seal materials are suitable, but for some hydraulic fluids only one kind is preferred. Suitable seal material allocated to the hydraulic fluid is shown in the table below. When ordering hydrostatic products the desired hydraulic fluid should be specified.

Sealing compatibility

Hydraulic fluid	Suitable test material according to ISO 6072
Mineral based hydraulic fluids	Standards: NBR 1, NBR 2 and FPM 2
Water-in-oil emulsions HFB	
Polyol esters HFDU	
Biodegradable synthetic esters HEES	
Triglycerides (vegetable-oil-based) HETG	
Poly(α-olefin) compounds and related hydrocarbons HEPR*	
Water/glycol mixtures HFC	Standards: NBR 1, NBR 2
Alkyl phosphate esters HFDR	Standard FPM 2
Aryl phosphate esters HFDR	
Poly(alkylene glycol) compounds HEPG	

* Depending on the base fluid other seal material may be recommended. Please contact fluid and/or seal manufacturer for other suitable materials.

General Information

Air in hydraulic fluid

Air in a system is regarded as a contaminant. Air increases the compressibility of the fluid, resulting in a "spongy" system that is less responsive. Air creates a loss of transmitted power, higher operating temperatures, increased noise levels, and loss of lubricity.

Air typically enters the circuit through the suction line if the seals and fittings are not tight. This free air then may be dissolved in the hydraulic fluid. Mineral based hydraulic fluid may contain up to 9 % volume percent dissolved air at atmospheric pressure.

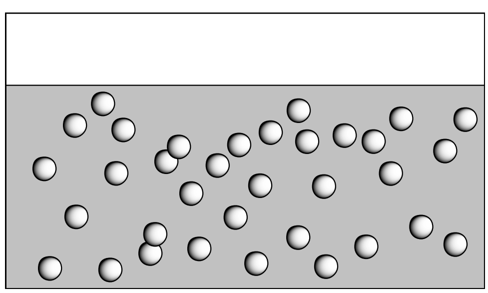
If 1 l [0.264 US gal] of hydraulic fluid is compressed to 100 bar [1450 psi], it may dissolve 9 l [2.377 US gal] of free air if offered.

This is not a problem unless the pressure drops down quickly to a lower level. Then the air becomes free again and bubbles show up. These bubbles collapse when subjected to pressure, which results in cavitation which causes erosion of the adjacent material. Because of this, the greater the air content within the oil, and the greater the vacuum in the inlet line, the more severe will be the resultant erosion.

The bubbles may also result in a spongy system, slow response time, and poor controllability. Therefore care must be taken to avoid air to enter the system. If air has entered a system the air release time and foam characteristic becomes important.

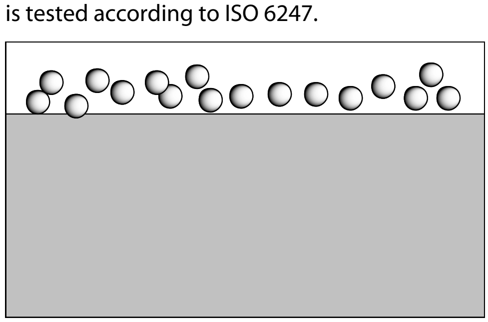
Air release

Air release is a measure for the time needed to release air bubbles (free air) contained in the fluid to the surfaces. Air typically enters the circuit through the suction line if the seals are not tight as explained above. Air release time is tested according to ISO 9120.



Foaming characteristic

Foaming characteristic defines the amount of foam collected on the surface in the reservoir and the air bubble decomposition time. Foaming may become a problem when air has entered the circuit as explained above, through an insufficient tight suction line. The foaming characteristic of a hydraulic fluid is tested according to ISO 6247.



General Information

Bulk modulus

While fluids are usually considered incompressible, the pressures that can occur in hydrostatic systems are of a magnitude that fluid compressibility can be significant. In applications that experience system pressure fluctuations resulting in random high pressure rise rates, consideration must be given to fluid compressibility when sizing a charge pump to ensure adequate charge pressure.

The amount that a specific fluid compresses for a given pressure increase is related to a fluid property known as the bulk modulus. The bulk modulus is a measure of a fluids resistance to being compressed. It depends on pressure and temperature. The air content is important as well especially below 50-100 bar [725-1450 psi]. The higher the air content the more spongy the system (lower bulk modulus). For a given pressure increase and fluid volume, a fluid with a large bulk modulus will experience a smaller reduction in volume than a fluid with a low bulk modulus.

Mathematically, bulk modulus is defined as follows:

$$E = \frac{\Delta \text{ pressure x initial Volume}}{\Delta \text{ Volume}} = \frac{\Delta p \cdot V_o}{\Delta V} = \text{bar [psi]}$$

Where:

E = bulk modulus of the fluid bar [psi]

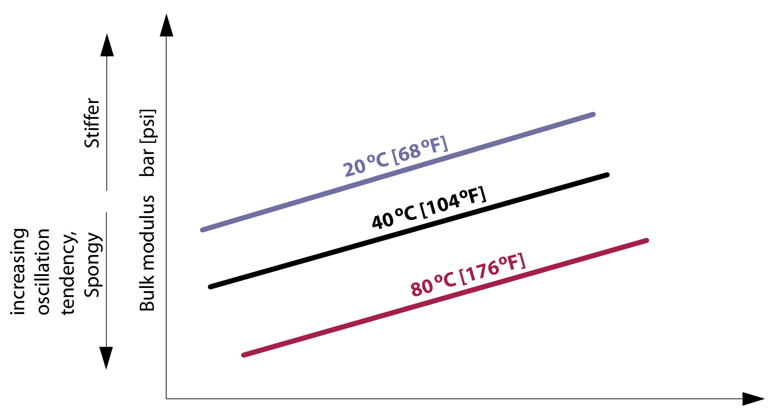
Δp = change in pressure bar [psi]

ΔV = change in volume l [US gal]

V_o = volume of oil experiencing the change in pressure l [US gal]

Units for bulk modulus are the same as the units for pressure.

Bulk modulus vs. Δ pressure for different temperatures



Bulk modulus **increases** with increasing pressure (stiffer) and **decreases** with increasing temperature (spongy).

Examples for bulk modulus at 22 °C [71.6 °F]

@Pressure	Water	HFC	HFD	Mineral (petroleum) HF
140 bar [2031 psi]	11 000	15 500	16 000	15 000
300 bar [4351 psi]	15 000	19 000	19 500	16 000

General Information

Compressibility

Compressibility is the reciprocal of the bulk modulus. It defines how much a fluid can be compressed.

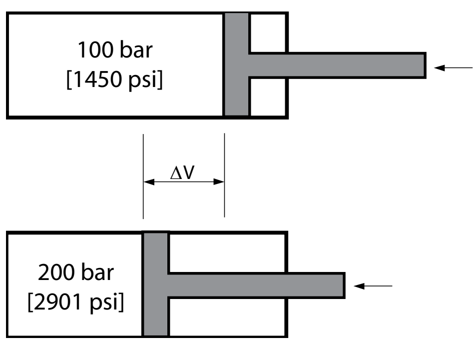
$$\text{Compressibility} = \frac{1}{E} = \frac{\Delta V}{\Delta p \times V_o} = \text{bar}^{-1}\ [\text{psi}^{-1}]$$

Examples for compressibility at 22 °C [71.6 °F]

@Pressure	Water	HFC	HFD	Mineral (petroleum) HF
140 bar [2031 psi]	91×10^{-6}	65×10^{-6}	63×10^{-6}	67×10^{-6}
300 bar [4351 psi]	67×10^{-6}	53×10^{-6}	51×10^{-6}	63×10^{-6}

Fluid compressibility becomes a concern for a hydrostatic system which has large volumes of oil under pressure, such as long or large system lines, and experiences high system pressure spikes during operation.

To understand the nature of the problem that can be associated with fluid compressibility, consider what happens when a system experiences an increase in load. An increase in load requires more torque from the motor, and consequently, an increase in system pressure. When the system pressure increases, the fluid in the high pressure side of the hydrostatic loop is compressed.



The illustration shows a simple model consisting of a cylinder whose piston compresses the fluid to create a pressure of 100 bar [1450 psi]. If a load forces the piston to move a small distance to the left, the fluid compresses even more, resulting in the pressure increasing to 200 bar [2900 psi].

The fluid at this pressure now occupies a smaller volume than the fluid did at 100 bar [1450 psi]. At the same time, the volume on the rod side of the piston increases. If we imagine that the rod side of the piston is also filled with fluid, then a void is created on this side of the piston when the fluid against the piston face is compressed. To keep the rod side of the piston full of fluid, additional fluid must be added to this side of the piston.

Calculation:

The hydraulic fluid volume under pressure in the cylinder is 10 l [2.64 US gal]. As approach the bulk modulus for 140 bar [2031 psi] as shown above is used.

$$\Delta V = \frac{\Delta p \cdot V_o}{E} = \frac{(200\text{-}100\ \text{bar}) \cdot 10\ \text{l}}{15\ 000\ \text{bar}} = 0.067\ \text{l}\ [0.0176\ \text{US gal}]$$

General Information

Water contamination

Non-dissolved water in a fluid is to be considered as contamination. It is one of the frequent reasons for the failure of a hydraulic system. Increased content of water in a lubricant can lead to corrosion of parts, water vapor cavitation, foam formation, filter clogging, oxidation of the fluid, depleting of additives and consequentially enhanced wear or a failure of the system.

Furthermore the polymer seal material could be attacked by the fluid leading to leakages.

The water contamination of the fluid can have different reasons as for example condensing of water, leakage of rain water into the system, leakage of cooling water and others.

Water solubility

Base oils of different types have limited water solubility. Blending the base oils with additives leads to a significant increase of the water solubility. Also the amount and the kind of used additive packages are crucial for this property. There is a general thumb rule: the higher the amount of additives, the higher the water solubility of a fluid. Consequently different fluid types have different water absorptive capacity, which depends on the molecular structure and the additive packages of the fluid. Some fluid types are able to dissolve more water by integrating it in the molecular structure, others less. When the absorbance of water reaches the saturation point, residual water separates from the fluid forming free water. Dissolved water in fluid is less harmfull than free water, since it is bound and has no reactivity. In case of pressure or temperature fluctuations dissolved water can get undissolved leading to an enormous change of fluid properties. The consequences of that are listed above. Strongly increased content of free water in a fluid can be detected optically, since it is leading to a clouding of the fluid.

The water in a fluid can be measured by different methods. Traditionally, Karl-Fischer-titration is used, which is used to determine the total water content. ISO 760 describes this procedure in general. Measuring the total water content means, there is no possibility to distinguish between the dissolved and undissolved water by using this method, making ppm values describing the water content often not sufficient enough.

Examples for critical water content of different fluids:

Fluid type	Critical water content
Mineral oil (HLP)	200 ppm — 500 ppm
Mineral oil with D-additives (HVLPD)	600 ppm — 1200 ppm
Biodegradable oil (HEES)	700 ppm
Fire resistant fluid (HFC=Water in Glycol emulsion)	> 4000 ppm
Universal Tractor Transition Oil (UTTO)	1000 ppm — 2000 ppm

Caution

All numbers in this table are only rough guides, which strongly differ in dependency with the used base oil, additive packages and the application of the hydraulic system.

Requirements for Hydraulic Fluids

Fluid type-related standards and specifications

Mineral oil based hydraulic fluids according to specification:

- **DIN 51524-2**: Mineral oil hydraulic fluids of category **HLP**
- **DIN 51524-3**: Mineral oil hydraulic fluids of category **HVLP**
- **ISO 11158**: Mineral oil hydraulic fluids of category **HM**
- **ISO 11158**: Mineral oil hydraulic fluids of category **HV**

Environmentally acceptable fluids according to specification ISO 15380 of category:

- **HEES** (synthetic esters) meeting Annex B of ISO 15380 (shear stability test & yellow metal test)
- **HETG** (tri-glycerides) meeting the same pour point specification as Category HEES and meeting Annex B of ISO 15380 (shear stability test & yellow metal test)
- **HEPG** (poly-glycols) meeting Annex B of ISO 15380 (shear stability test & yellow metal test)
- **HEPR** (poly-alpha-olefins, PAO)

Automatic Transmission Fluids (ATF) according to OEM specification

In additional to the international standards there is a variety of OEM specifications for fluids.

To meet the basic requirements for fluids all of the below mentioned ATF fluids must additionally meet the requirements of Table 3 in ISO 11158.

- GM ATF A Suffix A VI
- GM Dexron, which meets Allison C-4 and Caterpillar TO-4 test, downwards compatible with GM Dextron II or III
- Ford M2C33F and G
- Mercon V, Mercon LV
- ATF DW-1
- SP-IV or SP4
- Matic S, Matic L, Matic D
- ATF T-IV
- Toyota ATF-WS
- Honda DW

Gear Oils

In additional to the international standards there is a variety of gear oil specifications for fluids, which are described in ISO 12925-1. To meet the basic requirements for fluids both of the below mentioned gear fluids must additionally meet the requirements of Table 3 in ISO 11158.

- API GL-4
- API GL-5

Engine Oils

In additional to the international standards there is a variety of engine oil specifications for fluids, which are described in ISO 6743-15.

To meet the basic requirements for fluids all of the below mentioned engine oils must additionally meet the requirements of Table 3 in ISO 11158.

- Engine oils API Classification CI-4, CH-4, CG-4, CF-4 and CF (for diesel engines), where the latest category usually – but not always – includes the performance properties of an earlier category.
- Super Tractor Oil Universal (STOU), which meets the requirements up to API CF-4
- API GL4 with Limited- Slip (LS) additives

Requirements for Hydraulic Fluids

The following fluid classes meet the necessary requirements for the usage in hydrostatic units, but significant changes of the lifetime can be present:

- Premium Turbine Oils
- Tractor Oil Universal (TOU)
- Fire resistant fluids HFA, HFB, HFC, and HFD are suitable at modified operating parameters, but not with gear pumps and motors.

Contact the fluid manufacturer for more information about the suitability of a fluid in the expected application.

Fluid cleanliness

The cleanliness of a fluid is one of the most important features to guarantee a satisfying performance of the hydraulic system. Contamination of a fluid with solid particles can lead to a failure of the complete hydraulic system by locking of the pistons or blocking the valves. Different systems have different sensitivity to solid contamination of the fluid, so different levels of fluid cleanliness are determined by ISO 4406. The determination of the cleanliness level is made by counting the particles, distinguishing the particle size.

Further information to fluid cleanliness, filter compatibility in a system and the cleanliness levels can be found in the document *Design Guidelines for Hydraulic Fluid Cleanliness, Technical Information*, **BC00000095**.

Fluid change intervals

Danfoss recommends the following fluid change intervals for all fluids except those mentioned below:

- First change: 500 operating hours after start up
- Second and subsequent change every: 2000 operating hours or once a year

For HFA, HFB, HFC, HFD and biodegradable hydraulic fluids HETG shorter fluid change intervals are recommended:

- First change: 500 operating hours after start up
- Second and subsequent change every: 1000 operating hours or once a year

This recommendation applies for most applications. High temperatures and pressures will result in accelerated fluid aging and an earlier fluid change may be required. At lower fluid pressure loads longer change intervals are possible. Therefore we suggest taking a sample of the fluid at least one time, preferably more, between scheduled fluid changes. This fluid sample then can be sent to the fluid manufacturer or an appropriate laboratory for an analysis and a determination of its suitability for continued use.

Requirements for Hydraulic Fluids

Traces of wear metals and contamination

Wear metals are the result of corrosive wear due to water and acids but also abrasive wear due to surface roughness metal contact leading to welding. The table below shows typical amount of wear metals. In some mobile applications for copper numbers up to 300 mg/kg and aluminum up to 80 mg/kg have been found.

These metal traces are determined by Atom–Emission–Spectroscopy (AES) according to ASTM D5185-97. Typically particles smaller than 5 µm are detected. Larger particles are discussed below in the fluid cleanliness requirements section.

These metal traces may increase during operation. It is therefore important to monitor the wear metal concentration during operation. A sudden increase is an indication for a soon wear failure or that parts have been already damaged.

Typical values for traces of wear metal in hydraulic systems (mg/kg)

Fe	Cr	Sn	Al	Ni	Cu	Pb	Mo
30	10	10	10	2	50	15	5

Silicium (Si) has the highest percentage in dust and is contamination in a system. Silicium is very abrasive and a fluid change is recommended if 10–15 mg/kg are exceeded.

Requirements for Hydraulic Fluids

Viscosity and temperature limits

When using hydraulic fluid the viscosity and temperature limits in the table below are to be observed. Under normal operating condition it is recommended to keep the temperature in the range of 30°C to 60°C.

Fluid temperature affects the viscosity of the fluid and resulting lubricity and film thickness. High temperatures can also limit seal life, as most nonmetallic materials are adversely affected by use at elevated temperatures.

Fluids may break down or oxidize at high temperatures, reducing their lubricity and resulting in reduced life of the unit. As a rule of thumb, fluid temperature increase from 80 °C [176 °F] to 90 °C [194 °F] may reduce fluid life by 50%.

Overview on viscosity and temperature limits

Product line	Min. vicosity (intermit.) mm²/s [SUS]	Max. temperature (intermit.) °C [°F]	Recommended viscosity mm²/s [SUS]	Max. cold start viscosity mm²/s [SUS]	Min. temperature °C [°F]
H1B	5 [42.38]	115 [239]	12-80 [66.03-370.3]	1600 [7406]	-40 [-40]
H1P					
Series 15 Open circuit	12 [66.03]	85 [185]		860 [3981]	-20 [-4]
Series 20	7 [48.79]	95 [203]		1000 [4629]	-40 [-40]
Series 40		105 [221]		1600 [7406]	
Series 42		115 [239]			
Series 45	9 [55.51]	105 [221]		1000 [4629]	
Series 51	7 [48.79]	115 [239]		1600 [7406]	
Series 90	7 [48.79]	115 [239]			-40 [-40]
TMP/TMM					
LV/LC/KV/KC		105 [221]			
Hydrostatic steerings	10 [58.91]	90 [194]		1000 [4629]	-30 [-22]
Proportional valves	4 [39.17]			460 [2129]	
Electrohydraulic valves	12 [66.03]	82 [180]		440 [2037]	
Spool valves	6 [45.59]				
Orbital motors	12 [66.03]* 20 [97.69]**	90 [194]	20-80 [97.69-370.3]	1500 [6944]	

* For OMR, OMH, OMS, OMT, OMV, TMT

** For OML, OMM, OMP

Fire resistant fluids HFA, HFB, HFC, and biodegradable fluids HETG have limited temperature capabilities. Please see the individual fluids information given in this manual and contact the fluid manufacturer.

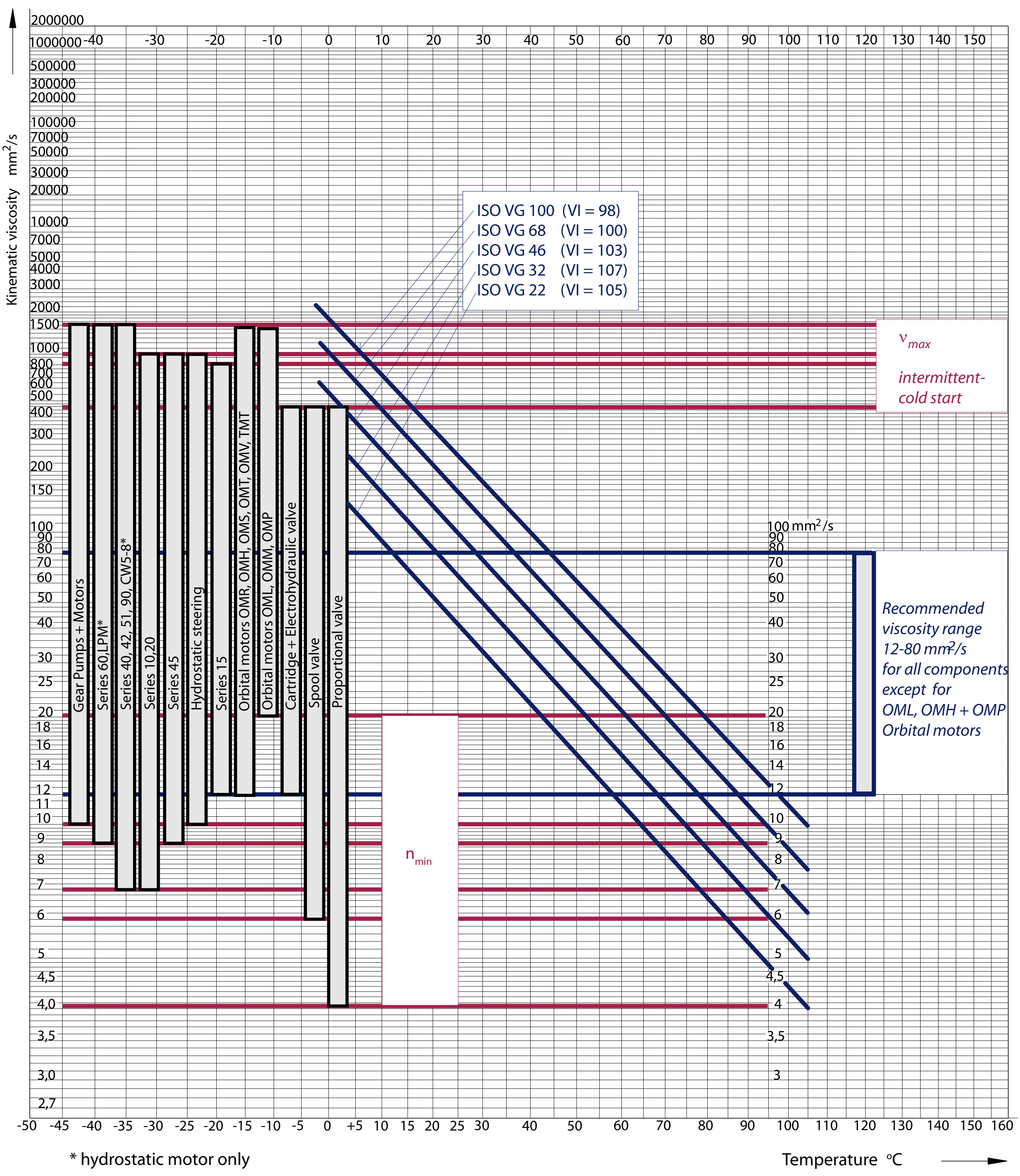
Viscosity – Temperature diagrams on page 18 shown on the next seven pages are for a reference only. Please check actual viscosity with fluid manufacturer.

For more information to specific product lines please check the technical information to corresponding product on the official *http://www.powersolutions.danfoss.com* website.

Requirements for Hydraulic Fluids

Viscosity – Temperature diagrams

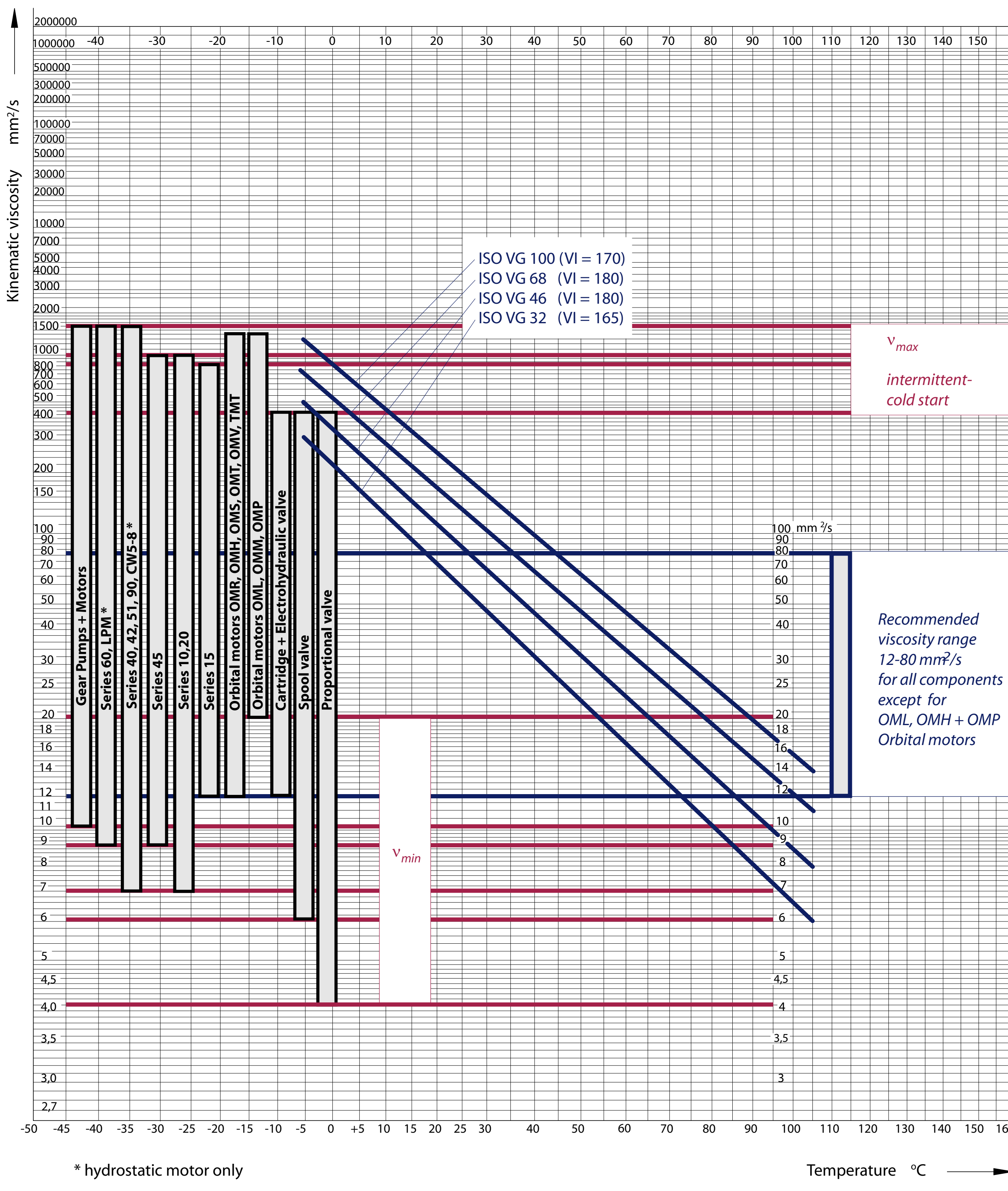
Hydraulic fluid according to DIN 51 524-2 HLP



* hydrostatic motor only

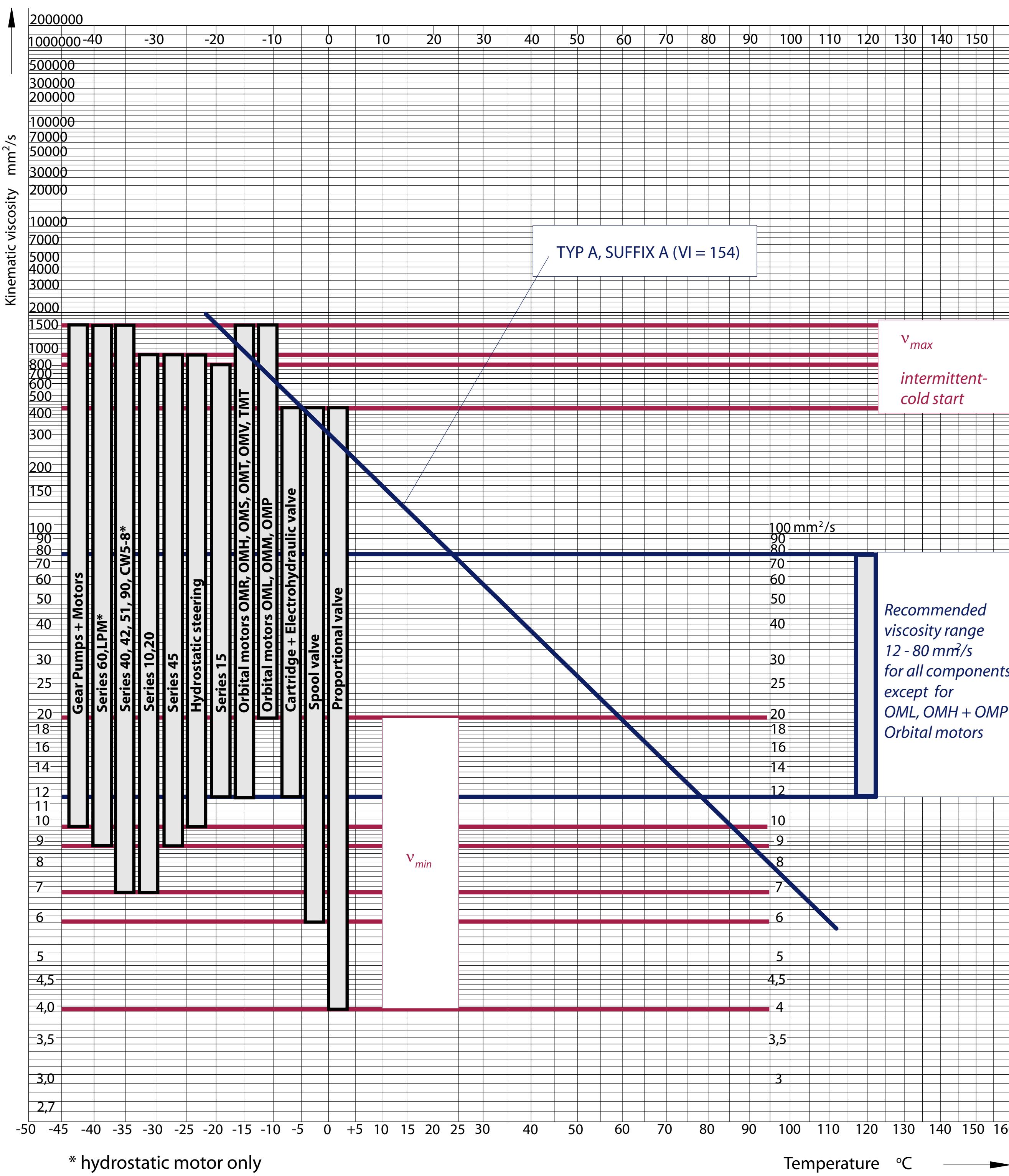
Requirements for Hydraulic Fluids

Hydraulic fluid according to DIN 51 524-3 HVLP



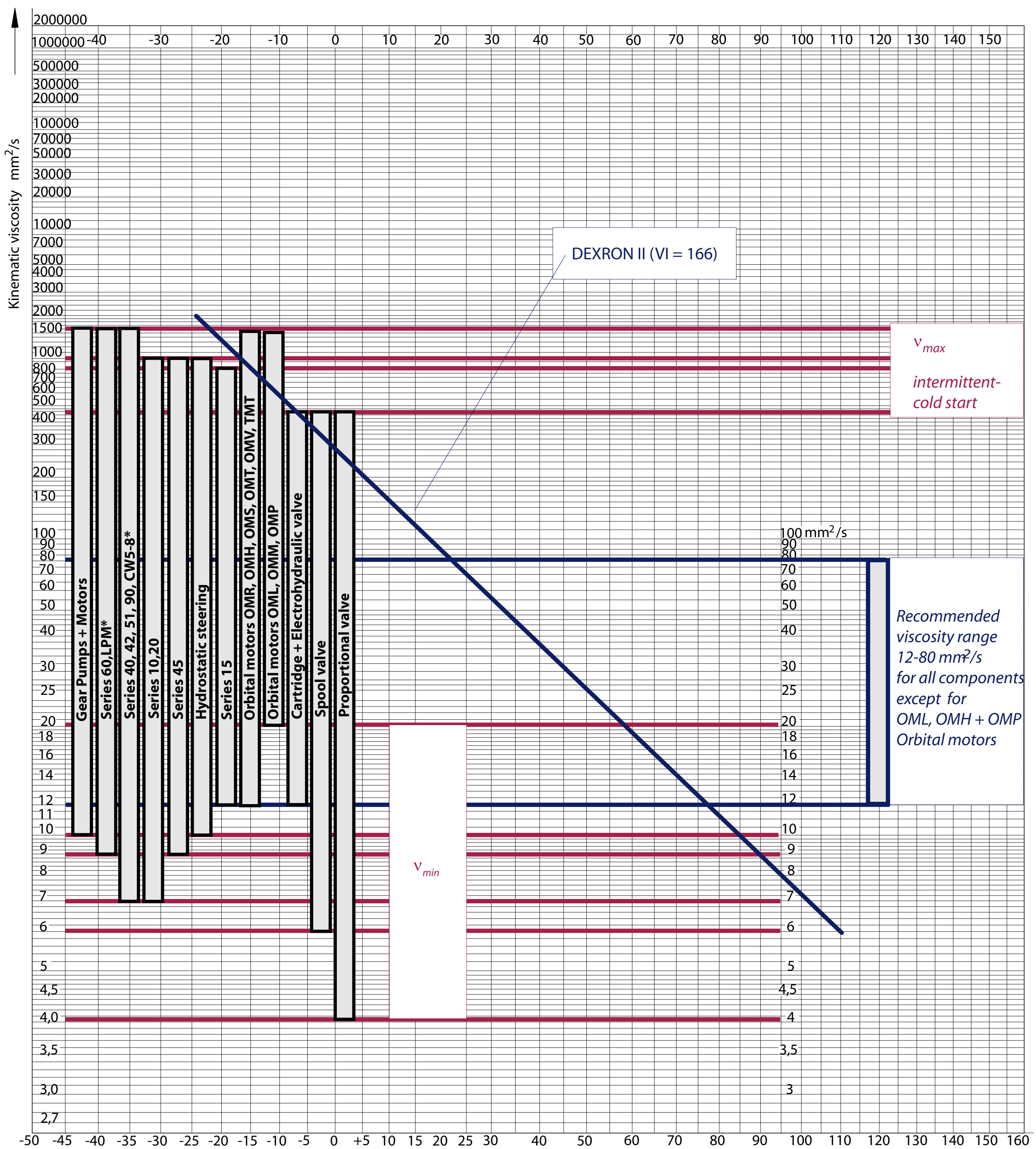
Requirements for Hydraulic Fluids

Automatic Transmission Fluids (ATF) typ A, SUFFIX A (GM)



Requirements for Hydraulic Fluids

Automatic Transmission Fluids (ATF) DEXRON II

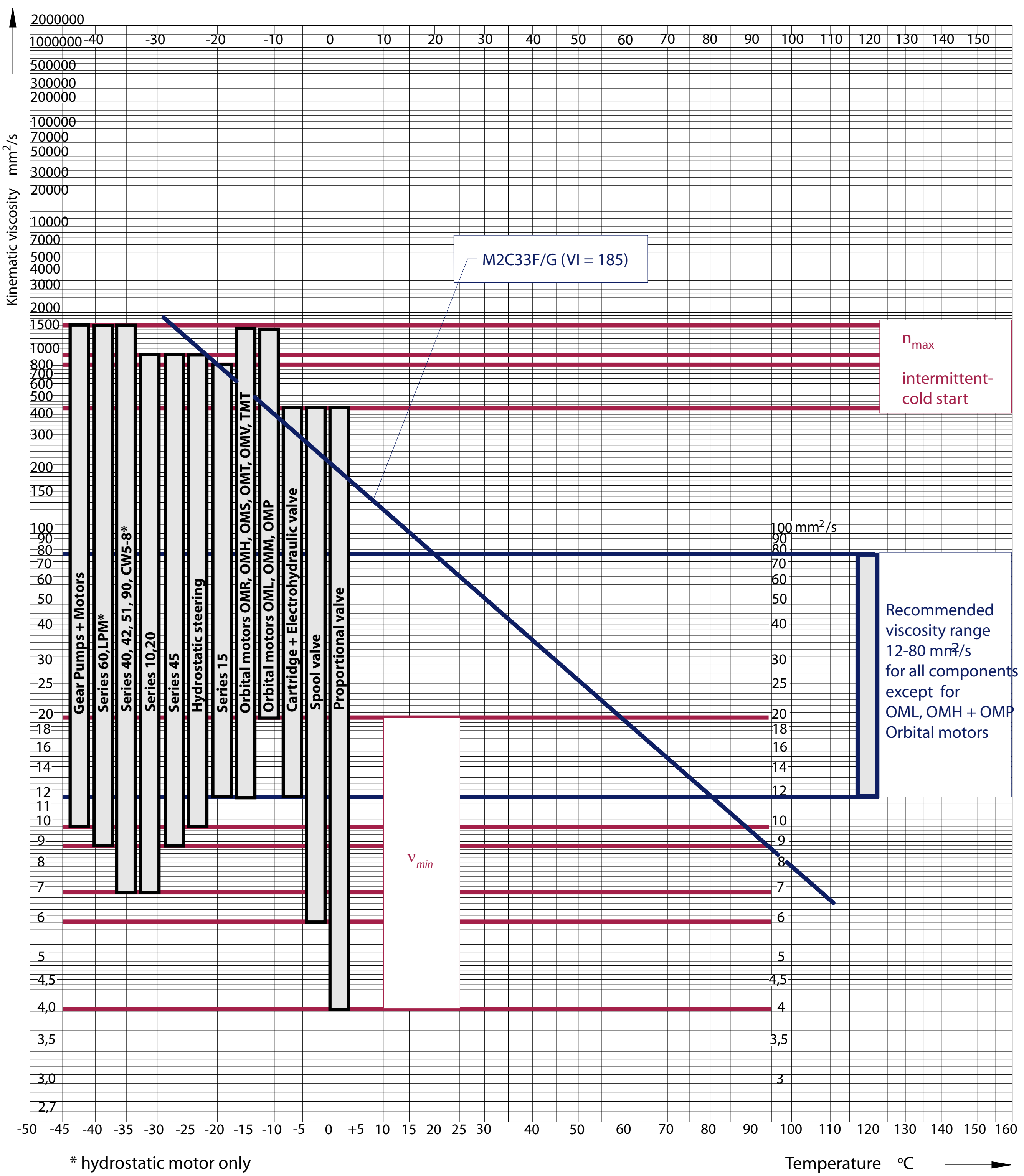


* hydrostatic motor only

P002 054E

Requirements for Hydraulic Fluids

Automatic Transmission Fluids (ATF) M2C33F/G, FORD

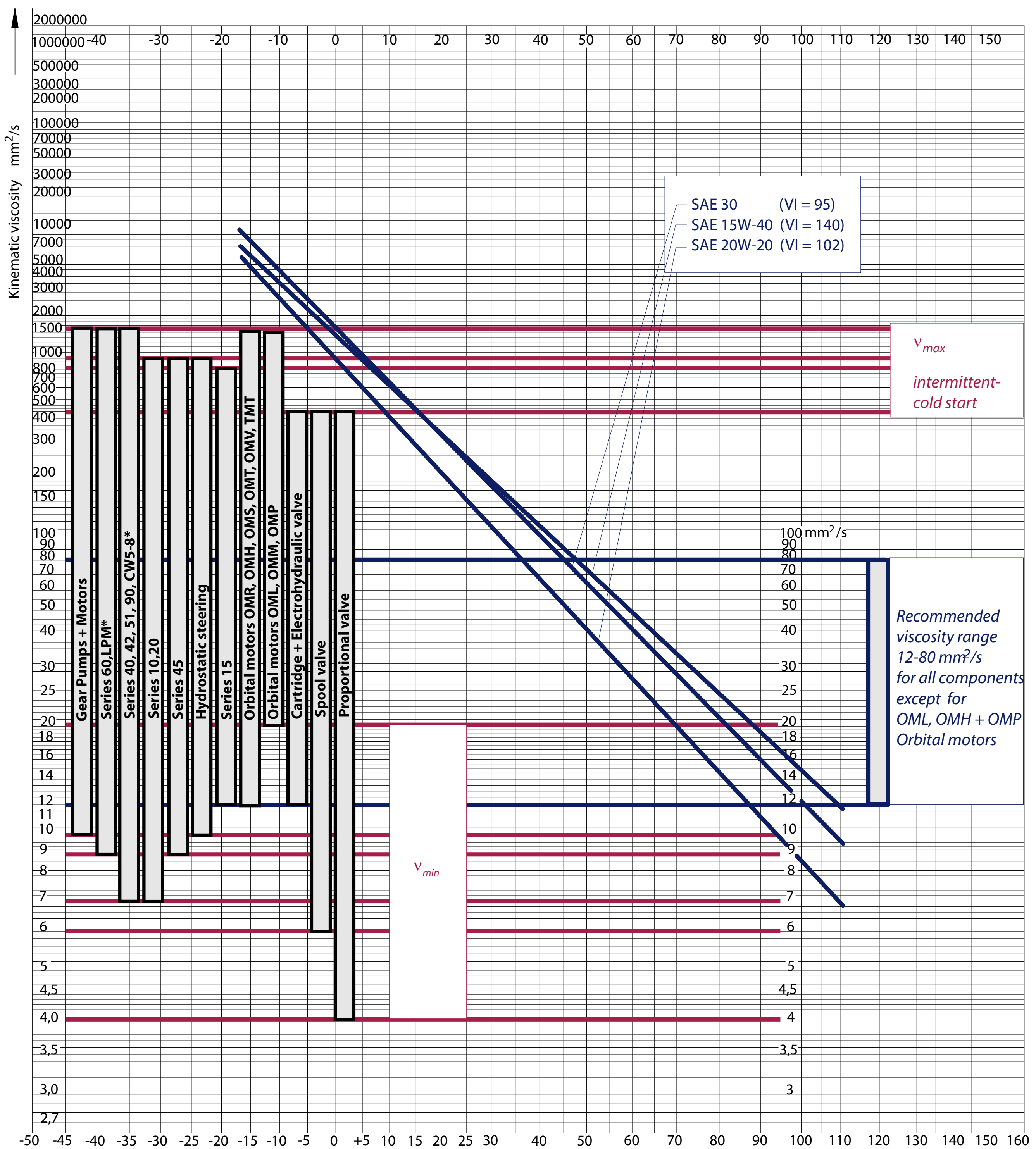


* hydrostatic motor only

P002 056E

Requirements for Hydraulic Fluids

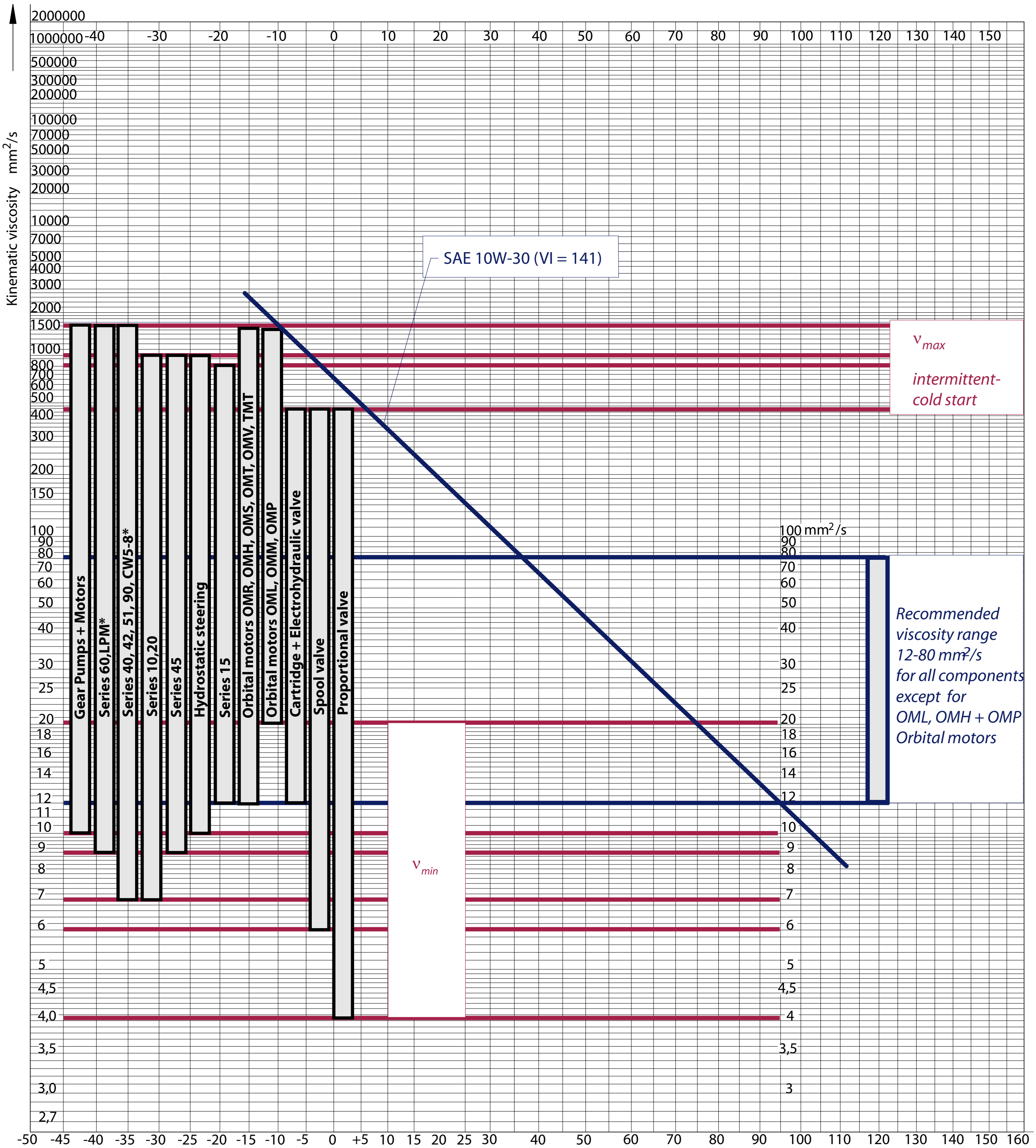
Engine oil per API classification CI-4, CH-4, CG-4, CF-4 and CF



* hydrostatic motor only

Requirements for Hydraulic Fluids

Multi Purpose Oil STOU - Super Tractor Oil Universal



* hydrostatic motor only

P002 058E

Fire Resistant Hydraulic Fluids

HFA fluids – oil in water emulsions, according to ISO 12 922.

By application of this fluid type, some problems with bacterial control and corrosion could occur. Fluid pH can become unstable and cause wear and chemical reaction with aluminum.

A positive head reservoir is required to maintain a positive inlet pressure when operating, and to keep air out of internal passageways when shut down. HFA fluids are divided into two groups:

HFAE Oil-in-Water emulsions with low emulsion oil content according to ISO 12 922. Normally these fluids contain 1 to 5% emulsion oil related to the volume.

HFAS Solutions with typically not more than 10% fluid concentrate in water according to ISO 12 922.

HFB fluids – water in oil emulsions, according to ISO 12 922.

These fluids can break down with repeated freezing and thawing. Also, heating above 60 °C [140 °F] can cause emulsion breakdown. High specific gravity requires an elevated reservoir and increased inlet line size.

Monitoring of fluid water content is necessary. Frequent additions may be necessary in order to overcome evaporation losses. These fluids also show poor vapor phase corrosion inhibition.

HFC fluids – water polymers / water glycols, according to ISO 12 922.

They attack zinc and cadmium, and produces solvent action on some paints. For more information contact the fluid manufacturer. Wear of aluminum in transmission parts sometimes occurs in the presence of these fluids.

Viton seals are not recommended. High specific gravity requires an elevated reservoir and increased inlet line size.

Water content and pH-number may be a problem.

HFD fluids – water free, synthetic fluids according to ISO 12 922.

Viton seals are required. Consult the fluid manufacturer to obtain a recommendation of the particular fluid used. These fluids attack some plastics, zinc and cadmium. High specific gravity requires an elevated reservoir and increased inlet line size. HFD fluids are divided into four groups:

HFDR Fluid based on Phosphorus acid Ester according to ISO 12 922. Used primarily in Great Britain in the mining industry.

HFDS Fluid based on Chlorinated Hydrocarbons. Used primarily in hydrodynamic clutches.

HFDT Fluid based on mixtures of Phosphorus acid Ester and Chlorinated Hydrocarbons. Used primarily in hydrostatic transmissions.

HFDU Other synthetic hydraulic fluids without water according to ISO 12 922. Used primarily in aviation hydrostatic.

Some of these fluids have caused high wear of aluminum parts in transmissions.

Fluid conversion

Consult ISO 7745 and the fluid manufacturer guidelines when converting to another hydraulic fluid. Use caution when converting an application to a different fluid. Thoroughly test the new fluid in the application before committing to the change.

Fire Resistant Hydraulic Fluids

General operating parameters for fire resistant hydraulic fluids

Danfoss hydrostatic products, except gear pumps and gear motors, may be used with fire resistant fluids under modified operating parameters as listed below.

In any case when ordering Danfoss products, please make sure you specify the desired fluid to be used. The appropriate seals or other modification will then be provided.

Operating parameters for fire resistant hydraulic fluids according to ISO 12 922

Type of fluid	HFA Oil in water emulsion	HFB Water in oil emulsion	HFC Watery polymer solution	HFD Water free synthetic
Operating temperature*	5 – 55 °C [40 – 130 °F]	5 – 60 °C [40 – 140 °F]	-20 – 60 °C [-4 – 140 °F]	10 – 70 °C [50 – 160 °F]
Water content*	> 80%	> 40%	> 35%	–
Typical roller bearing life**	< 5%	30 – 35%	10 – 20%	50 – 100%

* The temperature range and the water content are based on the specific fluid properties.

** Mineral based fluid is 100%.

Fire Resistant Hydraulic Fluids

Specific operating parameters for products running with fire resistant fluids

The specific operating parameters are based on the technical data shown in the Technical Information for each product. Fluid change intervals are modified as shown earlier in fluid change interval section.

Axial piston pumps and bent axis motors

Type of fluid	HFA	HFB	HFC	HFD
Speed	65%	65%	65%	100%
Differential pressure	40%	70%	60%	100%
Inlet pressure (bar abs. [in Hg])	1 [0]	0.95 [1.5]	0.95 [1.5]	0.95 [1.5]

Orbital motors

Type of fluid			HFA	HFB	HFC	HFD
Max. differential pressure* bar [psi]	OMM, OMP	cont.	50 [725]	70 [1015]	70 [1015]	70 [1015]
		interm.	70 [1015]	100 [1450]	100 [1450]	100 [1450]
	OMR	cont.	70 [1015]	100 [1450]	100 [1450]	100 [1450]
		interm.	100 [1450]	140 [2031]	140 [2031]	170 [2466]
	OMS, OMT, OMV	cont.	100 [1450]	140 [2031]	140 [2031]	170 [2466]
		interm.	140 [2031]	175 [2538]	175 [2538]	210 [3046]
Estimated life time (mineral based fluid is 100%)			2 - 5%	10 - 20%	10 - 15%	80 - 100%

* The above mentioned recommendations for maximum temperature limits are a guideline for most of applications.

Proportional valves

Fire resistant fluids may be used, but much lower lifetime, compared to mineral oil, may be expected. Low viscosity and high pressure may increase the internal leakage. Increasing internal leakage may cause erosion because of the higher fluid velocity. The wear caused by erosion is worsened if the fluid is contaminated.

The density and steam pressure for fire resistant fluids are different from mineral oils, and this may increase the risk of cavitation. Also the pressure drop is different, and this may influence the dynamics and stability of the valve. Therefore it is recommended to minimize pressure drop and keep working temperatures low.

Steering units

HFA, HFB, HFC and HFD-U fluids may be used, but much lower lifetime, compared to mineral oil, may be expected. Steering units may not operate with HFD-R fluids (phosphate ester).

Biodegradable Hydraulic Fluids

Biodegradable hydraulic fluids according to ISO 15 380

The growing environmental awareness has increased the research and development for biodegradable hydraulic fluids. Although these fluids have improved over the last years these are not yet ready to replace mineral based hydraulic fluids. Still several performance issues need to be improved.

The minimum technical requirements for biodegradable hydraulic fluids are specified in the German standard **VDMA 24 568** – Rapidly Biologically Degradable Hydraulic Fluids Minimum Technical Requirements

The ISO 15380 - lubricants, industrial oils and related products (class L) – family H (Hydraulic systems) – describes the fluid categories HETG, HEPG, HEES and HEPR providing guidance for suppliers and users of environmentally acceptable hydraulic fluids, and to advice manufacturers of hydraulic systems. This norm also stipulates the requirements for environmentally acceptable hydraulic fluids at the time of delivery.

Warning

To avoid damage caused by the hydraulic fluid we recommend to take fluid samples every 150 – 200 operating hours. The fluid manufacturer should check the further fluid usability.

All biodegradable hydraulic fluids are subject to special disposal regulations similar to mineral based hydraulic fluids. The legal national and international ordinances and regulations will apply. Particularly the instructions of the fluid manufacturer must be followed.

Many fluid manufacturers voluntarily offer to take back the used fluids.

Biodegradable Hydraulic Fluids

HETG - Triglyceride hydraulic fluids

Features:

- very good viscosity-temperature behavior
- high biological degradability
- water hazard class WGK 0
- good corrosion protection
- good compatibility with seals/gaskets
- density approximately 0.92 g/ml
- pour point approximately -10 °C to -25 °C [-50 to -77 °F].

  (The fluid may become solid after extended storage at low temperatures. For further questions please contact the fluid manufacturer.)
- the minimum requirements of ISO 15 380 are generally met.

Operating data:

Under consideration of the HETG fluid properties the temperature range, however, is limited to -15 °C to 70 °C [-59 °F to 158 °F].

In order to avoid accelerated aging of the fluid , tank temperatures above 60 °C [140 °F] should be avoided.

Warning

All hydraulic components are tested with mineral oil!

All housings must be drained completely before installation to avoid mixing of fluid types!

Change interval:

Fluid change intervals are modified as shown earlier in fluid change interval section.

Hints for transition:

ISO 15 380 and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in ISO 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HETG:

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level, which are described in the section *Requirements for Hydraulic Fluids* on page 14 must be met in addition to above mentioned requirements, especially the needed temperature limitations to prevent rapid fluid ageing.

Biodegradable Hydraulic Fluids

HEPG – Polyglycol hydraulic fluids

Features:

- very good viscosity-temperature behavior
- biologically degradable
- water hazard class WGK 0
- good corrosion protection
- partially unacceptable compatibility with seals/gaskets
- density > 1.0 g/ml
- pour point approximately -10 °C to -25 °C [-50 to -77 °F]
- the minimum requirements of ISO 15 380 are generally met.

Operating data:

Due to the higher density compared to mineral oil the permissible suction pressure must be strictly adhered to.

Warning

All hydraulic components are tested with mineral oil!
All housings must be drained completely before installation to avoid mixing of fluid types!

Hints for transition:

Based on a few particular characteristics of poly glycol based fluids, as for example,

- partially unacceptable paint incompatibility
- low seal/gasket compatibility
- no mixability with mineral oil

The exchange of fluids in existing installation may be very expensive. ISO 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in ISO 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HEPG:

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level, which are described in the section *Requirements for Hydraulic Fluids* on page 14 must be met in addition to above mentioned requirements.

Biodegradable Hydraulic Fluids

HEES – Synthetic ester based hydraulic fluids

Features:

- very good viscosity-temperature behavior
- biologically well degradable
- water hazard class WGK 0
- good corrosion protection
- good compatibility with seals/gaskets
- good lubricating characteristics
- good aging resistance
- density approximately 0.92 g/ml
- pour point approximately -10 °C to -25 °C [-50 to -77 °F]
- the minimum requirements of ISO 15 380 are generally met.

Operating data:

Due to the higher density compared to mineral oil the permissible suction pressure must be strictly adhered to.

Warning

All hydraulic components are tested with mineral oil!
All housings must be drained completely before installation to avoid mixing of fluid types!

Hints for transition:

ISO 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in ISO 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HEES:

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level, which are described in the section *Requirements for Hydraulic Fluids* on page 14 must be met in addition to above mentioned requirements, especially the needed temperature limitations to prevent rapid fluid ageing.

Biodegradable Hydraulic Fluids

HEPR – Polyalphaolefins and related hydrocarbon hydraulic fluids

Features:

- very good viscosity–temperature behavior
- reduced biologically degradability, especially at higher viscosities
- water hazard class WGK 1 – 2
- good corrosion protection
- may be incompatible with some seals/gaskets, it is recommended to check seal compatibility individually
- good lubricating characteristics
- good aging resistance
- density approximately 0.86 g/ml
- pour point approximately -20 °C to -40 °C [-68 to -104 °F]
- the minimum requirements of ISO 15 380 are generally met.

Operating data:

Due to the higher density compared to mineral oil the permissible suction pressure must be strictly adhered to.

Warning

All hydraulic components are tested with mineral oil!
All housings must be drained completely before installation to avoid mixing of fluid types!

Hints for transition:

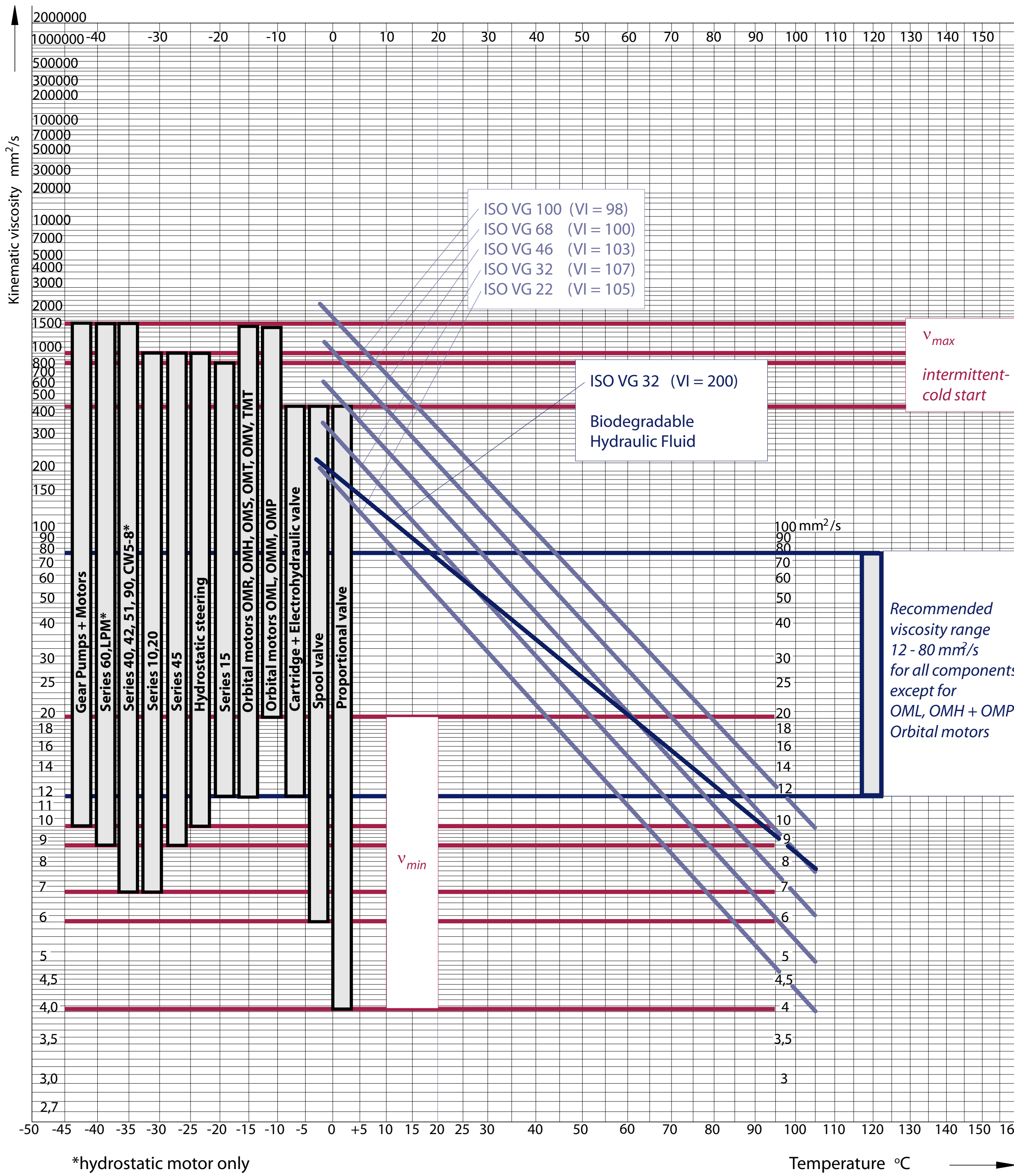
ISO 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in ISO 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HEPR:

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level, which are described in the section *Requirements for Hydraulic Fluids* must be met in addition to above mentioned requirements.

Biodegradable Hydraulic Fluids

Viscosity – Temperature Diagram



*hydrostatic motor only

P001 678E

Shown viscosity characteristics are for reference only. Please check actual viscosity with fluid manufacturer.

Gear Lubricants

Features

Gear lubricants have to perform the following tasks:

- Lubrication
- Heat removal

When choosing a gear lubricant the following features are most important for consideration:

- Viscosity
- Temperature sensitivity or viscosity Index (VI)
- Pour point
- Anti-wear or extreme pressure capabilities

For any particular application the features of the lubricant must be appropriate to the operating conditions of the unit and the regulations of the manufacturer.

For explanation of the terms Viscosity, Viscosity Index (VI) and Pour point see section *Hydraulic fluids*.

Gear lubricants specifications

The lubricants are to be chosen together with the gear manufacturer for each application. Danfoss gearboxes may be operated with a variety of lubricants.

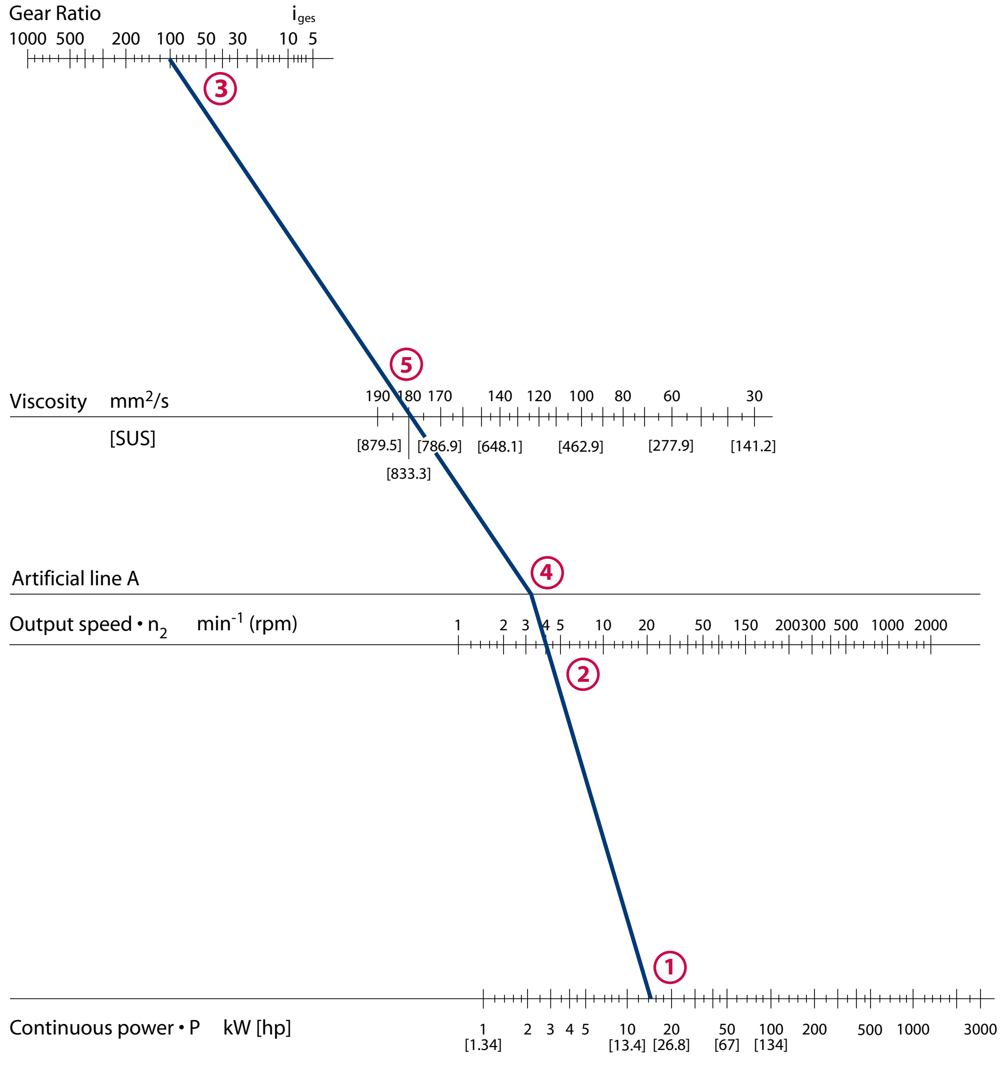
The following gear lubricants meet the basic requirements for application in Danfoss components:

- Lubricant DIN 51 517, part 3 - CLP
- Lubricant API-Classification GL4 or MIL-L-2105
- Lubricant API-Classification GL5 or MIL-L-2005

Gear Lubricants

Example for selecting the kinematic viscosity - transit mixer drive (agitate mode)

Nomograph for selection of kinematic viscosity for gear lubricants



Assumed:

1 Power: 15 kW [20 hp]
2 Output speed: 4 min^{-1} (rpm)
3 Gear ratio:i = 99 and Temperature: 55 °C [131 °F]

Nomograph:

5 Required viscosity at operating temperature: 180 mm^2/s [833.3 SUS]
Viscosity–temperature diagram - required lubricant: CLP 460

Warning

Determination of the viscosity is only a reference value.

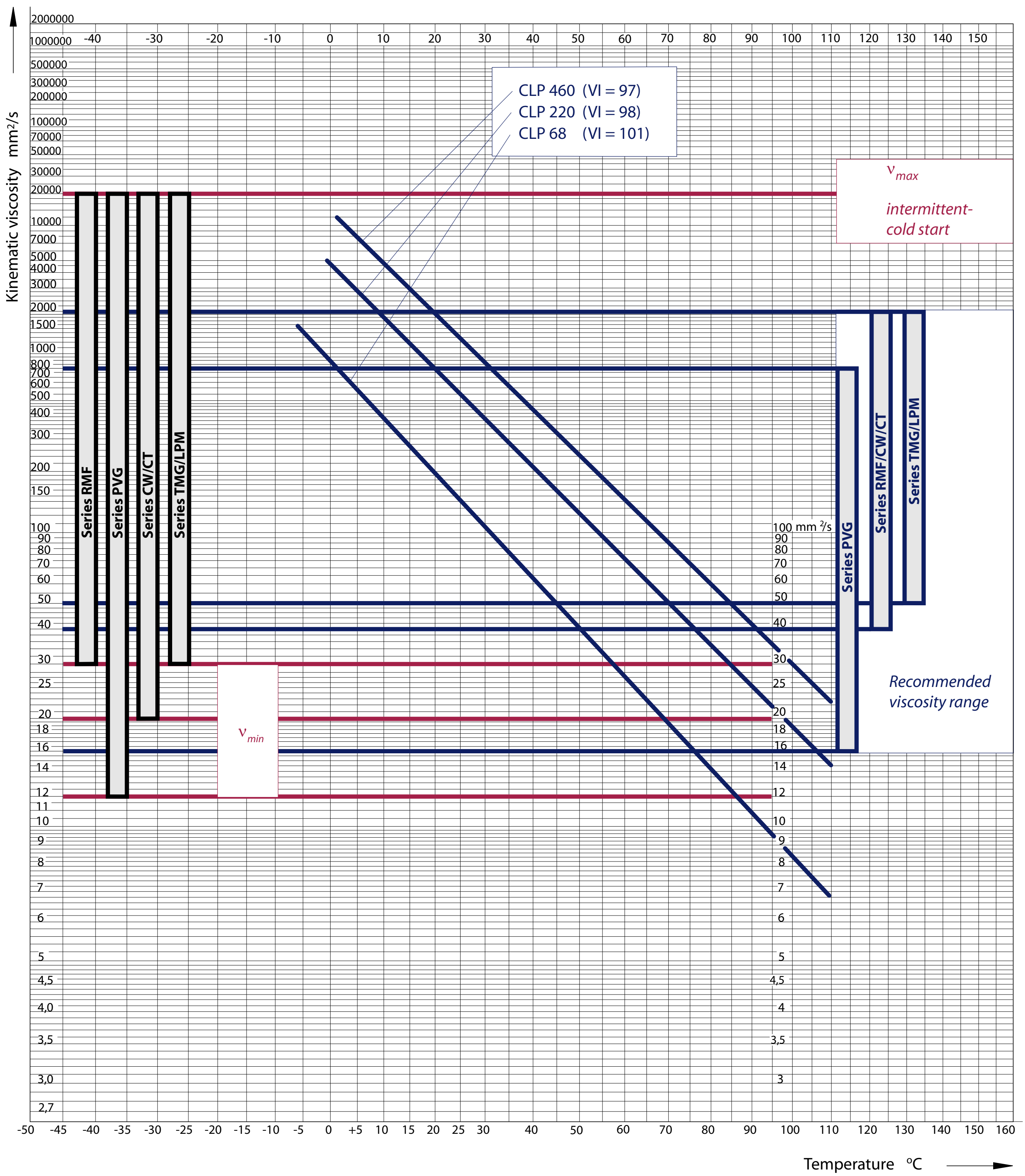
If the viscosity is between two different ISO viscosity grades, use the closests grade. For transit mixer boxes EP-Gear lubricants according to API-Classification GL-5 should always be selected.

Normally gear lubricants with SAE viscosity grade 90 show sufficient performance. At higher temperatures it is advisable to use Gear Lubricants with the SAE viscosity grade 140.

Gear Lubricants

Viscosity – Temperature diagrams

Lubricants according to DIN 51 517-3 - CLP



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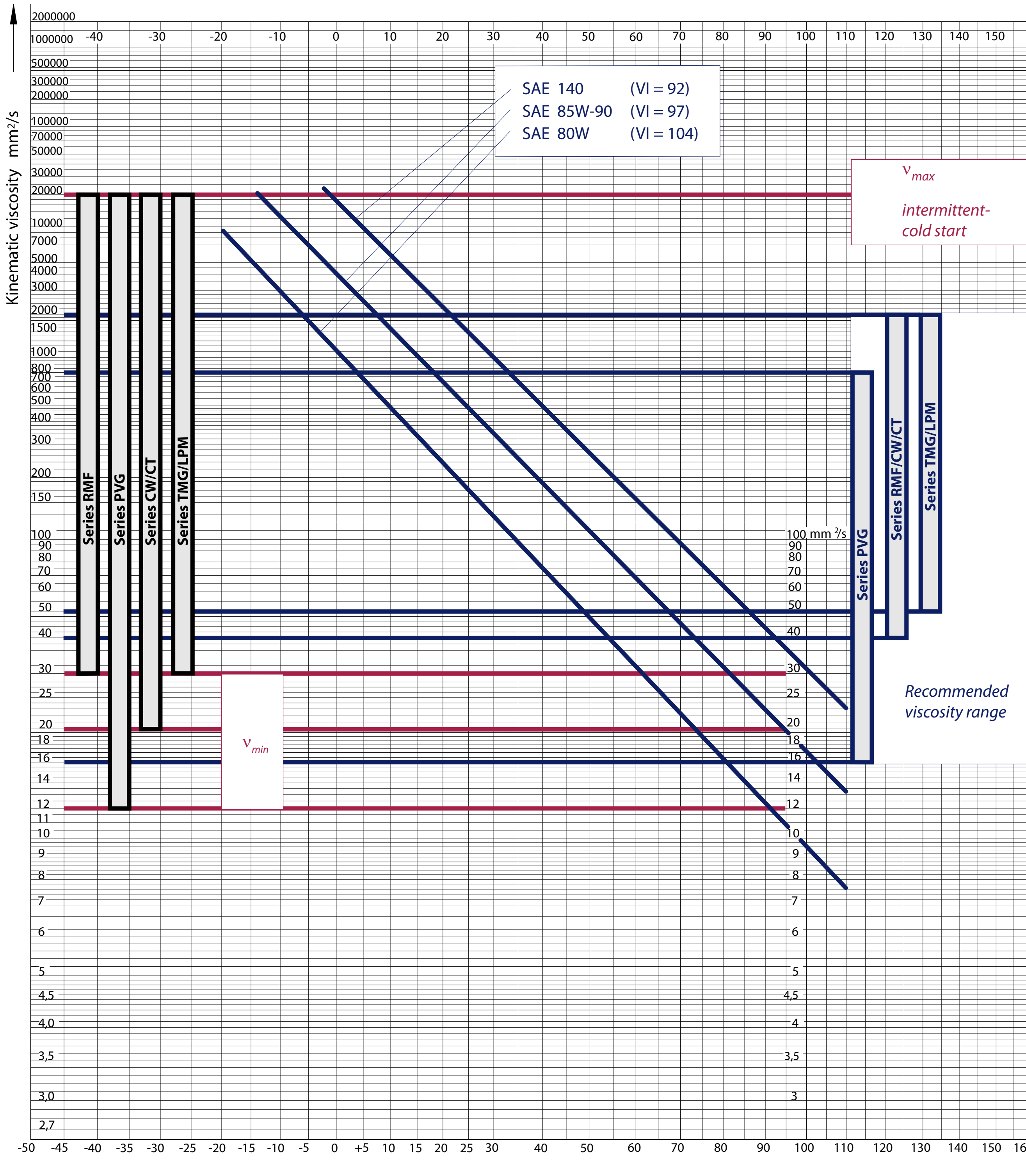
Gear Lubricants

Lubricants according to SAE API GL 4, MIL-L-2105, API GL5, MIL-2105 B



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Gear Bearing Grease

Features

Gear bearing grease has to perform the following task – **Lubrication**. Roller bearing grease does not flow out of the bearing housing. The free space of a roller bearing can be filled well due to the plastic, easily deformable structure. The filled grease quantity lubricates for a long period of time, as the required lubricant remains in the bearing.

Roller bearing greases serve to reduce friction wear and temperature and protect against corrosion. Bearing grease seals against external influences such as dust and humidity.

The high durability of a gear bearing grease avoids damage and machinery breakdown and increase the life of the gears. High-grade bearing grease has a wide range of uses. It distinguishes itself by constant temperatures, being waterproof and work endurance consistency. Furthermore, grease has a good oxidation stability and excellent corrosion protection.

Even at low temperatures the greases listed in the table are still easily transportable and render an easy bearing start-up possible.

Dropping point (ISO 2176)

The dropping point of a bearing grease is the temperature at which the first drop of grease brought to melting falls from an ISO 2176 standardized test unit. The dropping point of grease must always be above the intended bearing temperature.

Miscibility of gear bearing grease

Mixing of different soapanification agents is to be avoided. To be checked by grease manufacturer if desired. Such mixtures are often the cause of damage due to "liquefaction" or "hardening" of the grease mixture. When adjusting or even renewing the grease, remove the "old" grease completely.

Storage of gear bearing grease

Store grease in a dry area, if possible indoor. Buckets, large canisters or barrels are to be sealed with the lid immediately after use.

Consistency

The consistency index NGLI grade per ISO 6743-9 indicates how firm or soft a grease is. The following table provides a good survey:

Bearing grease, worked penetration

Consistency index NGLI	Consistency	Application in equipment
000	very high flowability	yes, central lubrication
00	high flowability	yes, gear-flowable grease
0	flowable	yes, gear-flowable grease
1	very soft	seldom
2	soft	yes, multipurpose grease
3	still soft	higher temperature
4	medium firm	no
5	firm	no
6	very firm	no

Preservation fluids and petroleum jelly

Features of preservation fluids

For longer periods of storage and shut down corrosion protection is necessary. Preservation fluids guarantee long-lasting protection against corrosion for hydrostatic transmissions and gears. In order to avoid corrosion which can result in shorter life and often high repair costs, corrosion protection is generally provided for in the following applications:

- For the dispatch of newly produced transmissions and gears and for longer time of transport, especially at sea.
- For the shutdown of transmissions and gears used periodically in vehicles, processing machines and systems (e. g. harvesters, construction machines, sugar refineries).
- For the dispatch of used vehicles and processing machines, e. g. to construction sites abroad.

Preservation fluids should be completely neutral as compared with hydraulic fluids or gear lubricants and other lubricants. In some cases compatibility testing between lubricating fluid and preservation fluid is required. When putting a machine into operation preservation fluid has to be drained. Additional cleaning should not be necessary. Contact distributors of hydraulic fluid and/or lubricant.

Warning

Mixing of fluids of different brands is not allowed.

The effort necessary for preservation depends on the length of shutdown or type of transport and the prevailing environmental conditions. Taking these factors into consideration, the following listed preservation measures are recommended:

- When filling transmissions and gears with hydraulic fluid, gear lubricant or preservation fluid use recommended fluid in respect to the environmental conditions of the operation in question (viscosity).
- When reoperating, drain preservation fluid and refill recommended fluid in respect to the environmental conditions of the operation in question.

Transport type	Shutdown period e.g. transport time	Code*
For dispatch of newly produced transmissions. Transport by rail or truck.	up to 6 month	A, E, G
	up to 12 month	A, F, G
For dispatch of newly produced transmissions. Sea transport.	up to 3 month	A, F, G
	up to 12 month	C, F, G
For shutdown of transmissions and gears used periodically in vehicles, process machines.	up to 6 month	B, E, G
	up to 12 month	B, F, G
For dispatch of gears and transmissions used in vehicles or process machines. Transport by rail or truck.	up to 6 month	B, E, G
	up to 12 month	B, F, G
For dispatch of gears and transmissions used in vehicles or process machines. Sea transport.	up to 3 month	B, F, G
	up to 6 month	D, F, G

* For furter details about codes see the table below.

Code	Preservation measure
A	Fill component with recommended hydraulic fluid or gear lubricant.
B	Change to recommended hydraulic fluid or gear lubricant.
C	Fill component or gear with recommended preservation fluid.
D	Change to recommended preservation fluid.
E	Grease piston rod when erected.
F	Preserve piston rod with long duration wax corrosion protection. Wrap air breather of transmissions and gears with strong plastic foil.
G	Install or change to new filters and/or air breathers.

Preservation fluids and petroleum jelly

Features and application of petroleum jelly

Petroleum jelly is used for assembly assistance and should be dissolved in the hydraulic fluid during operation of the hydrostatic unit. To ensure this, the application operating temperature should be above freezing point of the jelly (contact lubricants manufacturer).

Locking nozzles and throttle areas can therefore be avoided. Nevertheless, avoid overflow of the petroleum jelly between surfaces during assembly.

The mentioned petroleum jelly is used for adhering O-rings and seals when mounting hydrostatic transmissions and gears so that they are fixed securely to the housing surfaces and in the annular grooves and recesses.

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