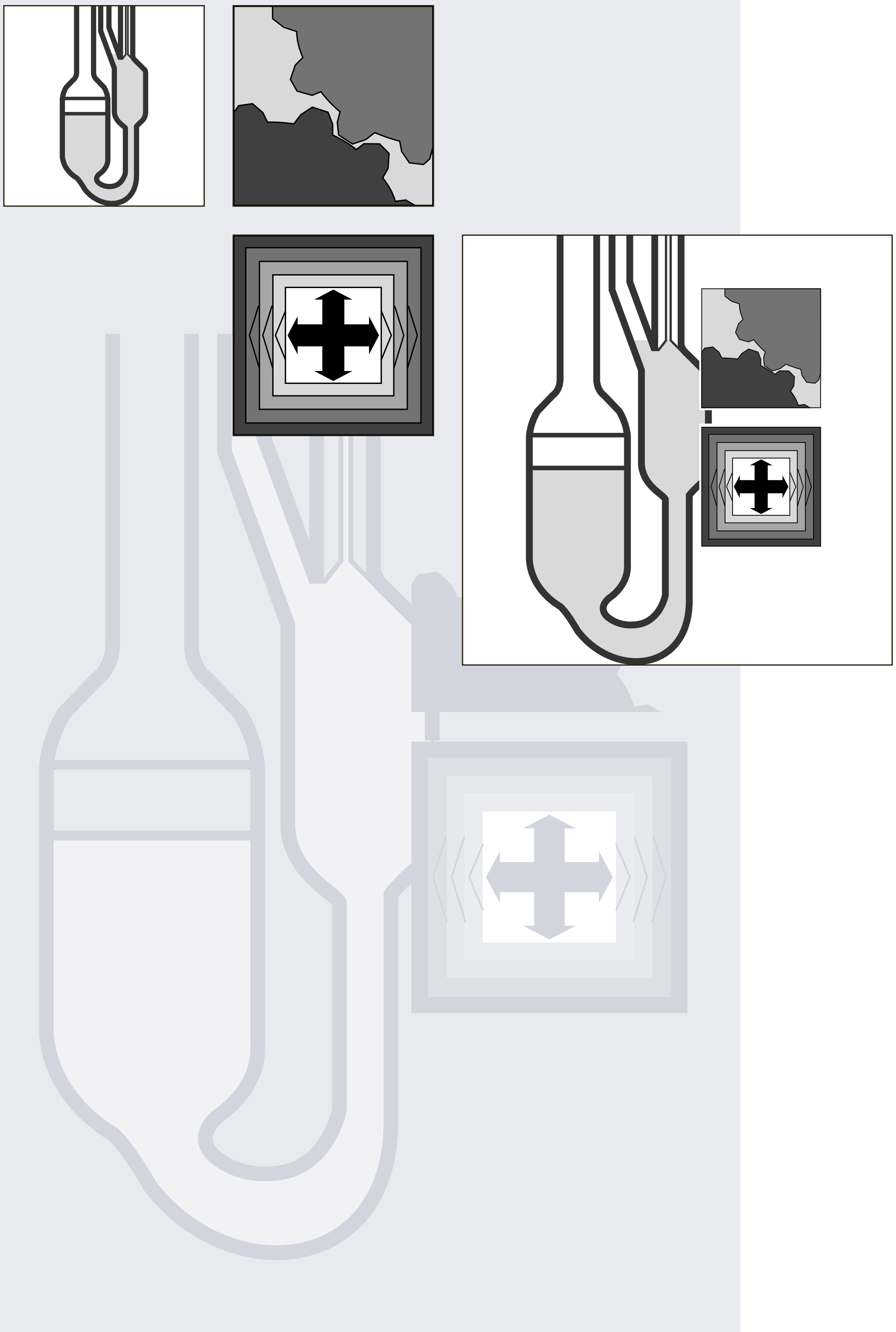
SAUER DANFOSS

Hydraulic Fluids and Lubricants

Technical Information



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 are 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 *Safety instructions.*
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.

Front cover illustrations: P001 945, P001 946, P001 944, P001 356.

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FIRE RESISTANT HYDRAULIC FLUIDS

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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 drinking 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.

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 table gives an outline of the necessary 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:	
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; • adequately low 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.

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage.
It is not permissible to mix lubricants. The different additive package may cause negative interactions. If lubricants mixing can not be avoided, fluid manufacturers approval is required.

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage which result from mixing.

HYDRAULIC FLUID FEATURES (continued)

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 following is an explanation of the fundamental features of the hydraulic fluids:

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):

$$\eta = \nu \cdot \rho = \text{(mPa·s)}$$

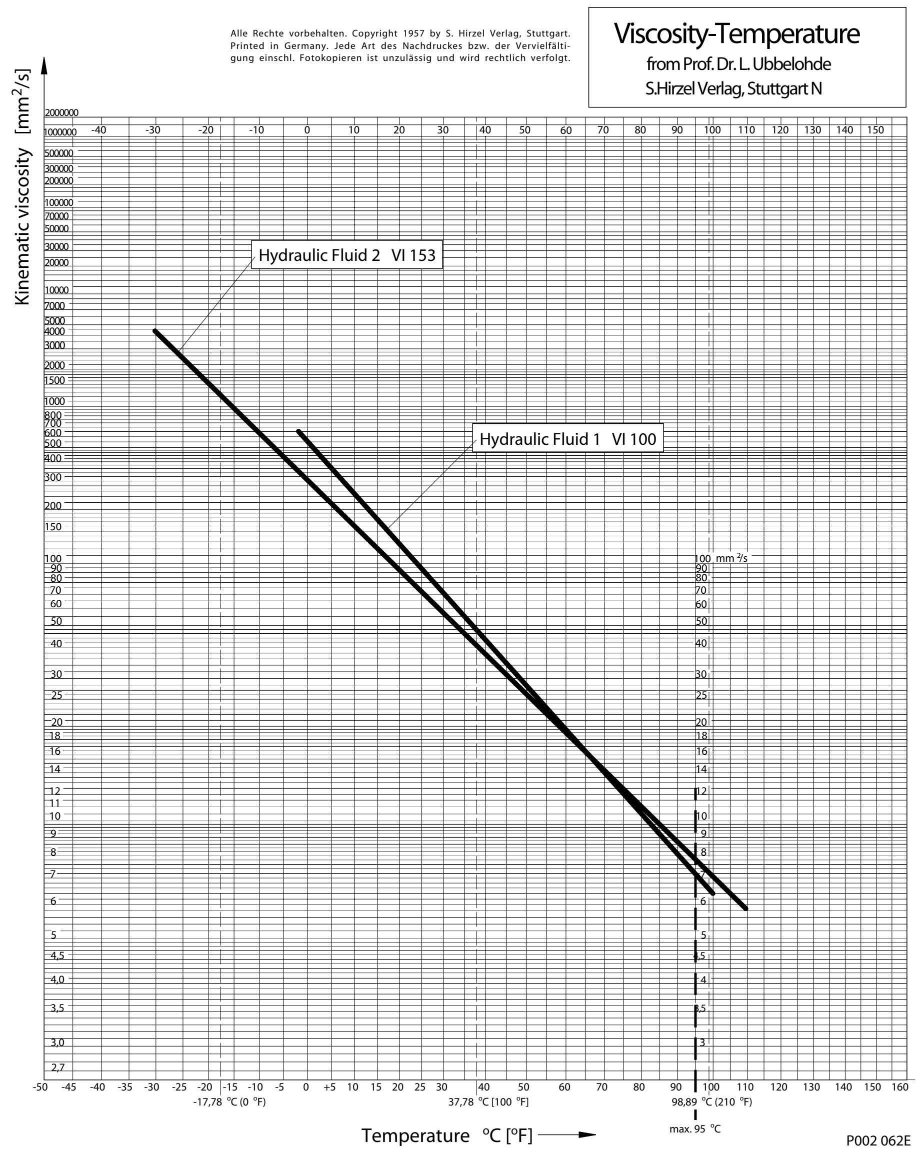
HYDRAULIC FLUID FEATURES (continued)

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 versus 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).



Most hydraulic fluids have a VI value of 90 - 110. 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.

HYDRAULIC FLUID FEATURES (continued)

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])

Petroleum (mineral) based fluids	0.860 - 0.900 g/ml
Synthetic Ester	0.920 - 0.926 g/ml
Rape Seed Oil	0.920 g/ml
Water	1.000 g/ml
Polyalkylenglycol	1.020 g/ml
HFC	1.080 g/ml
Polyethylenglycol	1.100 g/ml
HFD (Phoshate ester)	1.130 g/ml

Sealing compatibility

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	Seal material
Mineral based hydraulic fluid	NBR / FPM
Fire resistant fluid, HFA (water - oil emulsion)	NBR / FPM
Fire resistant fluid, HFB (oil - water emulsion)	NBR / FPM
Fire resistant fluid, HFC (water - glycol)	NBR
Fire resistant fluid, HFD (water free)	FPM*
Biodegradable fluid, HETG (tryglycerides)	NBR / FPM
Biodegradable fluid, HEPG (polyglycol)	FPM
Biodegradable fluid, HEES (synthetic ester)	NBR / FPM
Biodegradable fluid, HEPR (polyalphaolefins and related hydrocarbons)	FPM*

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

HYDRAULIC FLUID FEATURES (continued)

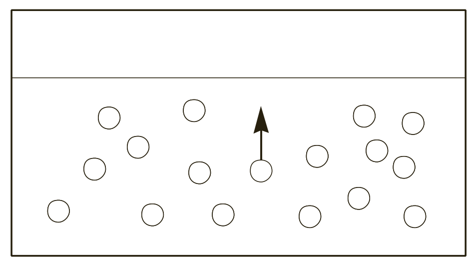
Air in the hydraulic fluid

Free air is considered as contamination as well. 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.

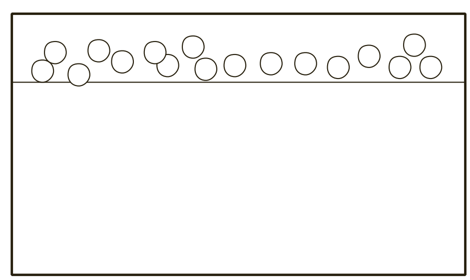
Air release

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 DIN 51 381.



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 DIN 51 566 .



HYDRAULIC FLUID FEATURES (continued)

Bulk modulus/Compressibility

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:

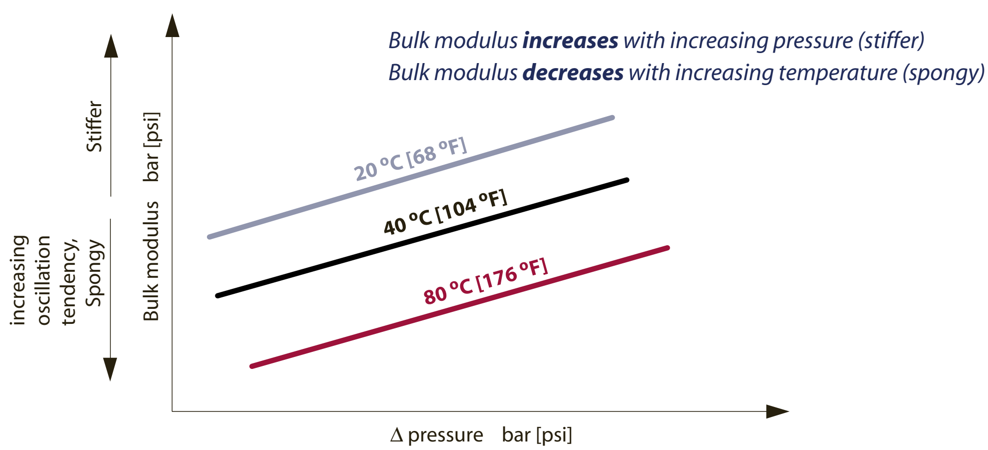
$$E = \frac{\Delta \text{ pressure x initial Volume}}{\Delta \text{ Volume}} = \frac{\Delta p \cdot V_o}{\Delta V} = \text{bar [psi]}$$

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]

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

Bulk modulus vs. Δ pressure for different temperatures



Another term often used is compressibility. It defines how much a fluid can be compressed. Compressibility is the reciprocal of the bulk modulus.

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

HYDRAULIC FLUID FEATURES (continued)

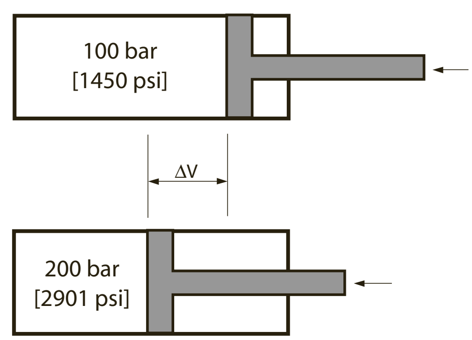
Examples for bulk modulus and compressibility at 22 °C [71.6 °F] and 140 bar [2031 psi] and 300 bar [4351 psi]

	Bulk modulus bar [psi]		**Compressibility** bar^{-1} [psi^{-1}]	
	140 bar [2031 psi]	300 bar [4351 psi]	140 bar [2031 psi]	300 bar [4351 psi]
Water	11 000	15 000	91 x 10^{-6}	67 x 10^{-6}
HFC	15 500	19 000	65 x 10^{-6}	53 x 10^{-6}
HFD	16 000	19 500	63 x 10^{-6}	51 x 10^{-6}
Mineral (petroleum) based hydraulic fluid	15 000	16 000	67 x 10^{-6}	63 x 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 below 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.



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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.

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

CLEANLINESS FEATURES

Definition of cleanliness levels per ISO 4406

The cleanliness level of a hydraulic fluid is determined by counting number and size of particles in the fluid. The number of particles is defined as a cleanliness level according to ISO 4406.

Definition of cleanliness levels per ISO 4406

Number of particles per 100 ml	Number of particles per 1 ml	Cleanliness levels per ISO 4406
1-2	0.01 - 0.02	1
2-4	0.02 - 0.04	2
4-8	0.04 - 0.08	3
8-16	0.08 - 0.16	4
16-32	0.16 - 0.32	5
32-64	0.32 - 0.64	6
etc.	etc.	etc.
4×10^3 - 8×10^3	40 - 80	13
8×10^3 - 16×10^3	80 - 160	14
16×10^3 - 32×10^3	160 - 320	15
32×10^3 - 64×10^3	320 - 640	16
64×10^3 - 130×10^3	640 - 1300	17
130×10^3 - 250×10^3	1300 - 2500	18
250×10^3 - 500×10^3	2500 - 5000	19

The step to the next cleanliness level means double or half the number of particles.

The old ISO 4406-1987 defines the cleanliness level of particles larger than 5 µm and 15 µm. As an example: if 1910 particles/ml larger than 5 µm and 71 particles/ml larger than 15 µm are counted, the ISO 4406-1987 code level is 18/13.
In 1999 both,the definition for particle counting and the definition of ISO code was changed. The required cleanliness class definition is now determined by ISO 4406-1999. The allocated particle sizes are:

Comparison of old and new standard ISO 4406

Old ISO 4406-1987	New ISO 4406-1999
not defined	4 µm (c)
5 µm	6 µm (c)
15 µm	14 µm (c)

Please note, that "(c)" must be added to the new definition in order to identify that it is the new ISO 4406. The old method for particle counting may still be used.

The ISO 4406-1999 cleanliness class 22/18/13 means:

22 specifies the number of particles larger than **4 µm** (c),
18 specifies the number of particles larger than **6 µm** (c), and
13 specifies the number of particles larger than **14 µm** (c) related to 1 ml respectively 100 ml of the inspected fluid.

CLEANLINESS FEATURES (continued)

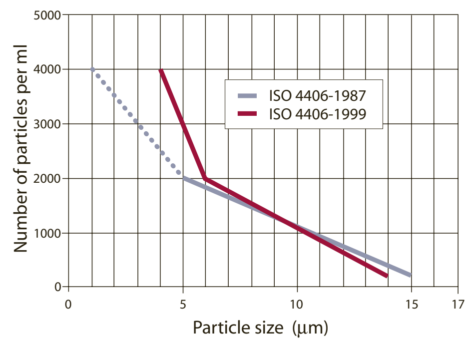
Measurements with the same fluid sample will result in the same cleanliness class for both methods as shown *in the table below*.

Number of particles per milliliter, particle count comparison

Particle size	1 µm	4 µm (c)	5 µm	6 µm (c)	14 µm (c)	15 µm
Not standardized	4000	-	-	-	-	-
Old ISO 4406-1987	-	-	2000	-	-	180
New ISO 4406-1999	-	4000	-	2000	180	-
ISO 4406 cleanliness class	19	19	18	18	15	15

The new method counts more smaller particles and less larger particles.
For better understanding please see *the graph beside*. This graph demonstrates the effect of the change to the new particle sizes 4 µm (c), 6 µm (c), and 14 µm (c).
Again, the actual number of particles of a sample is of course the same, only the counting method is different. Although it may look like, the new method does not allow more particles!

ISO 4406-1999 versus prior cleanliness classes



Together with this ISO 4406 change a new calibration standard ISO 11 171-1999 and a new Multipass test ISO 16 889-1999 for filters have been developed.

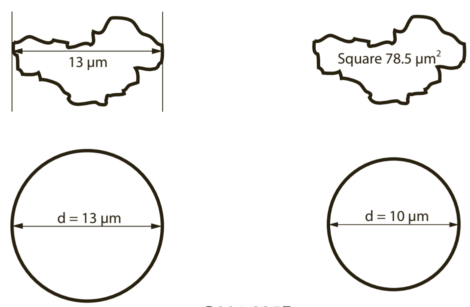
Comparison between old and new standards

Old standards	Test description	New standards
ISO 4402-1991	Automatic particle counter (APC) calibration	ISO 11 171-1999
ISO 4406-1987	Cleanliness code	ISO 4406-1999
ISO 5472-1982	Multipass test for filters	ISO 16 889-1999

CLEANLINESS FEATURES (continued)

New particle size definition

The particle size definition has been changed also. The old standard defined the largest particle extension as the particle size. The new standard uses the projected square area and converts this to an equivalent diameter. Please see *the picture below*.



$$d = \frac{\sqrt{78.5\ \mu m^2 \cdot 4}}{\pi} = 10\ \mu m$$

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ISO 4407 (under revision) specifies particle counting with a microscope. Only particles larger 5 µm and 15 µm are manually counted and specified as –/18/13. The "–" is used in place of the first scale number, while 18 is allocated to 5 µm and 13 to 15 µm.

Recommendation for filter fineness/retaining rates (Beta-ratios)

Recommended β-ratios		
Suction filtration (closed + open circuit)		$\beta_{35\text{-}45} = 75$ ($\beta_{10} \geq 2$)
Charge pressure filtration (closed circuit)		$\beta_{15\text{-}20} = 75$ ($\beta_{10} \geq 10$)
Return line filtration (open circuit)	general	$\beta_{35\text{-}45} = 75$ ($\beta_{10} \geq 2$)
	for gear pumps and motors	$\beta_{15\text{-}20} = 75$ ($\beta_{10} \geq 10$)

For charge pressure and return line filtration a suction screen with a mesh width of 100 – 125 µm must be used in the suction line to prevent sudden damage due to large particles.
Please see *Design Guideline for Hydraulic Fluid Cleanliness, Technical Information, 520L0467* for further information on how the cleanliness requirements can be achieved.

TECHNICAL REQUIREMENTS OF HYDRAULIC FLUIDS

Water content per DIN ISO 3733

In a new fluid the water content must be out of the quantitative detectable range. Unless otherwise specified in individual fluid standards the water content for continuous operation must not exceed 0,1 % (1000 mg/kg). The lower the better. In principle water is a harmful contaminant, reducing the life of the hydraulic fluid and the mechanical components. Water in a system may result in corrosion, cavitation, and altered fluid viscosity. Depending on the fluid, water may also react with the fluid to create harmful chemical by-products or destroy important additives. Left unchecked, water contamination may result in microbial growth. At this stage, system components may already have been damaged.
Experiments with a HLP-Oil with a water content of 1 % led to a significant pressure rise at the filter, which had as a consequence the destruction of the filter due to swelling and therefore an increase of the differential pressure.

The water content requirements **do not** apply for **HFA, HFB, HFC**–fluids**.**

Air content

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

Fluid change intervals

Sauer-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 for an analysis and a determination of its suitability for continued use.

TECHNICAL REQUIREMENTS OF HYDRAULIC FLUIDS (continued)

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 E DIN 51 396 and 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 see *the table below.*

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

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

Fluid cleanliness requirements

To achieve the specified unit life a cleanliness level as shown below must be met. Fluid samples shall be taken either in the loop or at the entry to the pump which is typically the suction line.
Fluid cleanliness requirements depends on the product and the products acceptable continuous or rated pressure limits.

Fluid cleanliness requirements according to product

Product	Required cleanliness class ISO 4406-1999	Curve in the diagram *on page 12*
Steering components with open center	22/20/17	**A**
Orbital motors	22/20/16	**B**
Steering components with LS and closed center	21/19/16	**C**
Proportional spool valves		
Axial + radial piston pumps and motors	22/18/13	**D**
Gear pumps and motors		
Cartridge and electrohydraulic valves	18/16/13	**E**

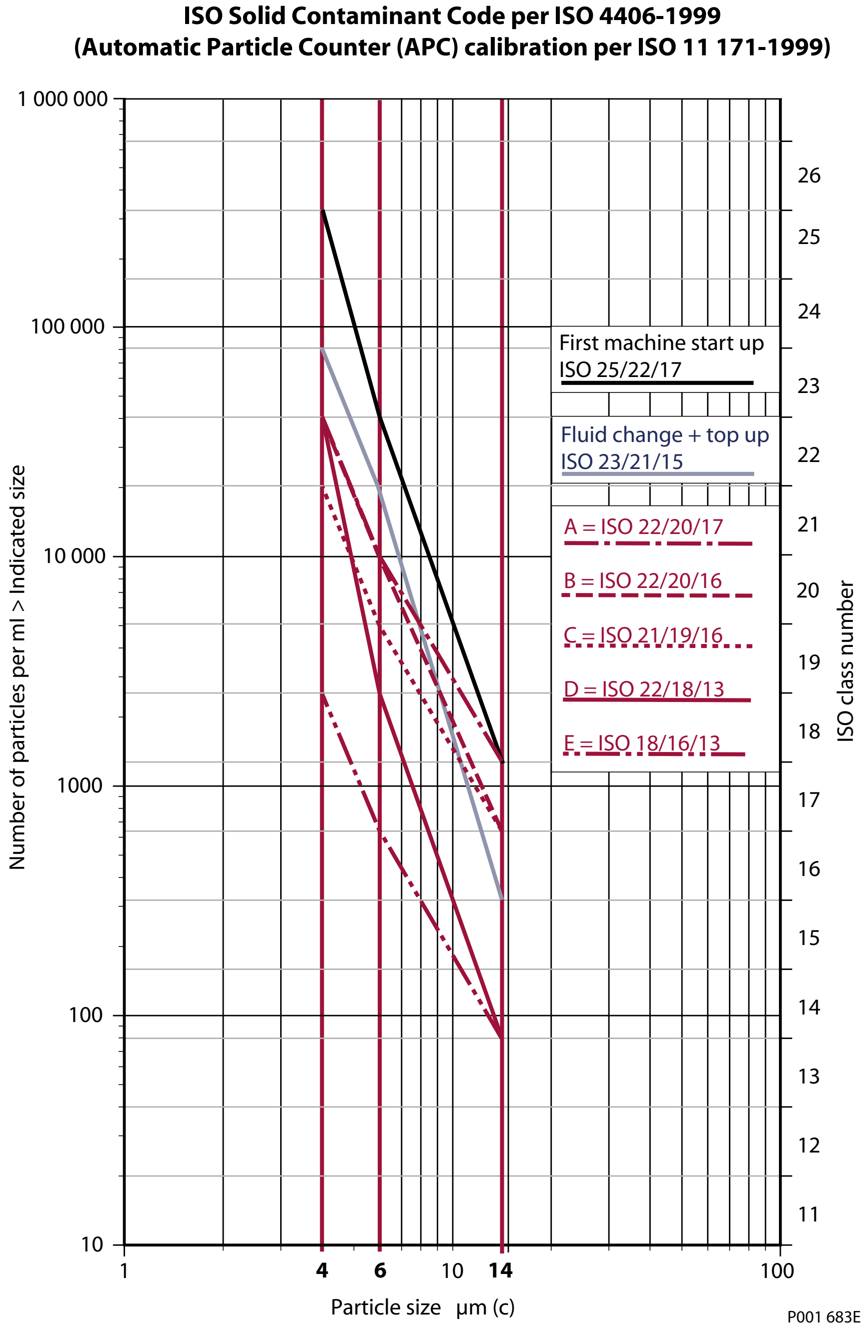
These cleanliness levels can not be applied for hydraulic fluid residing in the component housing/case or any other cavity after transport.

In general for fluid change and new fluid top up minimum cleanliness class 23/21/15 and for first machine start up at the factory minimum cleanliness 25/22/17 must be met if not otherwise specified. Exceeding these levels may result in start-up damage.

The before mentioned requirements reflect the experience gained from a broad range of applications. For very high lifetime requirements or contamination sensitive components (e.g. servo valves) better cleanliness levels are necessary.

TECHNICAL REQUIREMENTS OF HYDRAULIC FLUIDS (continued)

Required fluid cleanliness diagram



TECHNICAL REQUIREMENTS OF HYDRAULIC FLUIDS (continued)

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 %.

Viscosity and temperature limits

<table>
<tr><th>Product line</th><th>Min. vicosity (intermittent) mm²/s [SUS]</th><th>Maximum temperature (intermittent) °C [°F]</th><th>Recommended viscosity mm²/s [SUS]</th><th>Maximum cold start viscosity mm²/s [SUS]</th><th>Minimum temperature °C [°F]</th></tr>
<tr><td>Series 10</td><td>7 [48.79]</td><td>95 [203]</td><td rowspan="19">12-80 [66.03-370.3]</td><td>1000 [4629]</td><td>-40 [-40]</td></tr>
<tr><td>Series 15 Open circuit</td><td>12 [66.03]</td><td>85 [185]</td><td>860 [3981]</td><td>-20 [-4]</td></tr>
<tr><td>Series 20</td><td rowspan="3">7 [48.79]</td><td>95 [203]</td><td>1000 [4629]</td><td rowspan="5">-40 [-40]</td></tr>
<tr><td>Series 40</td><td>105 [221]</td><td rowspan="2">1600 [7406]</td></tr>
<tr><td>Series 42</td><td>115 [239]</td></tr>
<tr><td>Series 45</td><td>9 [55.51]</td><td>105 [221]</td><td>1000 [4629]</td></tr>
<tr><td>Series 51</td><td>7 [48.79]</td><td>115 [239]</td><td rowspan="5">1600 [7406]</td></tr>
<tr><td>Series 60</td><td>9 [55.51]</td><td>85 [185]</td><td>-20 [-4]</td></tr>
<tr><td>Series 90</td><td rowspan="3">7 [48.79]</td><td rowspan="2">115 [239]</td><td rowspan="3">-40 [-40]</td></tr>
<tr><td>TMP/TMM</td></tr>
<tr><td>LV/LC/KV/KC</td><td>105 [221]</td></tr>
<tr><td>Gear pumps and motors</td><td>10 [58.91]</td><td>80 [176]</td><td>1000 [4629]
1600 [7406]***</td><td>-20 [-4]</td></tr>
<tr><td>RMF (hydrostatic motor only)</td><td rowspan="2">7 [48.79]</td><td>95 [203]</td><td>1000 [4629]</td><td rowspan="2">-40 [-40]</td></tr>
<tr><td>CW 5-8 (hydrostatic motor only)</td><td>115 [239]</td><td>1600 [7406]</td></tr>
<tr><td>Hydrostatic steerings</td><td>10 [58.91]</td><td rowspan="2">90 [194]</td><td>1000 [4629]</td><td rowspan="6">-30 [-22]</td></tr>
<tr><td>Proportional valves (PVG)</td><td>4 [39.17]</td><td>460 [2129]</td></tr>
<tr><td>Cartridge valves</td><td rowspan="2">12 [66.03]</td><td rowspan="3">82 [180]</td><td rowspan="3">440 [2037]</td></tr>
<tr><td>Electrohydraulic valves</td></tr>
<tr><td>Spool valves</td><td>6 [45.59]</td></tr>
<tr><td>Orbital motors</td><td>12 [66.03]*
20 [97.69]**</td><td>90 [194]</td><td>20-80 [97.69-370.3]</td><td>1500 [6944]</td></tr>
</table>

* for OMR, OMH, OMS, OMT, OMV, TMT
** for OML, OMM, OMP
*** for Group 2

Note: 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.

GENERAL

Sauer-Danfoss hydrostatic components may be operated with a variety of hydraulic fluids.

The rated data which we publish in our Technical Information and Service Manuals are based on the use of premium hydraulic fluids containing oxidation, rust, and foam inhibitors. These fluids must also possess good thermal and hydrolytic stability to prevent wear erosion, and corrosion of the internal components. For some applications good anti-wear additives are required.

The following hydraulic fluids are suitable:
- Hydraulic Oil ISO 11 158 - HM (Seal compatibility and vane pump wear resistance per DIN 51 524-2 must be met)
- Hydraulic Oil ISO 11 158 - HV (Seal compatibility and vane pump wear resistance per DIN 51 524-3 must be met)
- Hydraulic Oil DIN 51 524-2 - HLP
- Hydraulic Oil DIN 51 524-3 - HVLP
- Automatic Transmission Fluid ATF A Suffix A (GM)
- Automatic Transmission Fluid Dexron II (GM), which meets Allison C-3 and Caterpillar TO-2 test
- Automatic Transmission Fluid M2C33F and G (Ford)
- Engine oils API Classification SL, SJ (for gasoline engines) and CI-4, CH-4, CG-4, CF-4 and CF (for diesel engines)
- Super Tractor Oil Universal (STOU) special agricultural tractor fluid

Contact Sauer-Danfoss and/or follow further mentioned information before using:
- Premium Turbine Oils
- Automatic Transmission Fluid Dexron III (GM)
- Universal Tractor Fluids
- Biodegradable hydraulic fluids HETG, HEPG, HEES, and HEPR per VDMA 24 568 and ISO 15 380 meeting Annex B of ISO 15 380
  - DIN 51 350-6 Taper Roller Bearing Shear Stability test for fluids containing polymers (ISO 20 844 Diesel Injector Nozzle Shear Stability test only for medium duty applications)
  - VDMA 24 570 Yellow Metal Compatibility test
- Fire resistant fluids HFA, HFB, HFC, and HFD are suitable at modified operating parameters, but not with Gear Pumps and Motors.

Fluids meeting these requirements will very likely provide acceptable unit life, but field testing is the only truly indication of fluid performance.

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage.

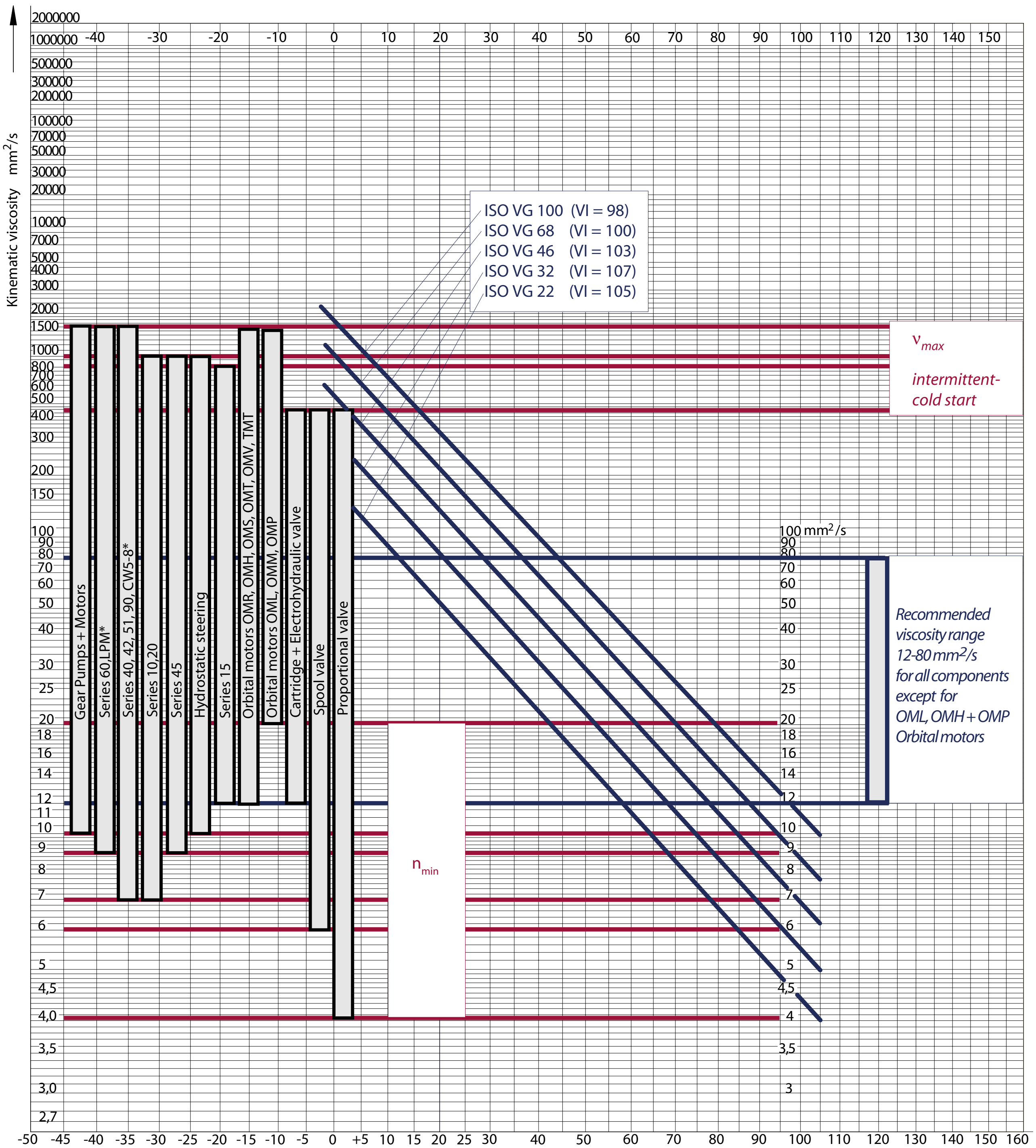
It is not permissible to mix hydraulic fluids. The different additive packages may cause negative interactions. If hydraulic fluid mixing can not be avoided, fluid manufacturers approval is required. The Sauer-Danfoss warranty claim policies do not apply for fluid related damage which result from mixing.

REQUIRENENTS FOR MINERAL BASED HYDRAULIC FLUIDS

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level described in the section *Requirements of hydraulic fluids* must be met.

HYDRAULIC FLUID ACCORDING TO DIN 51 524-2 HLP, VISCOSITY – TEMPERATURE DIAGRAM

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

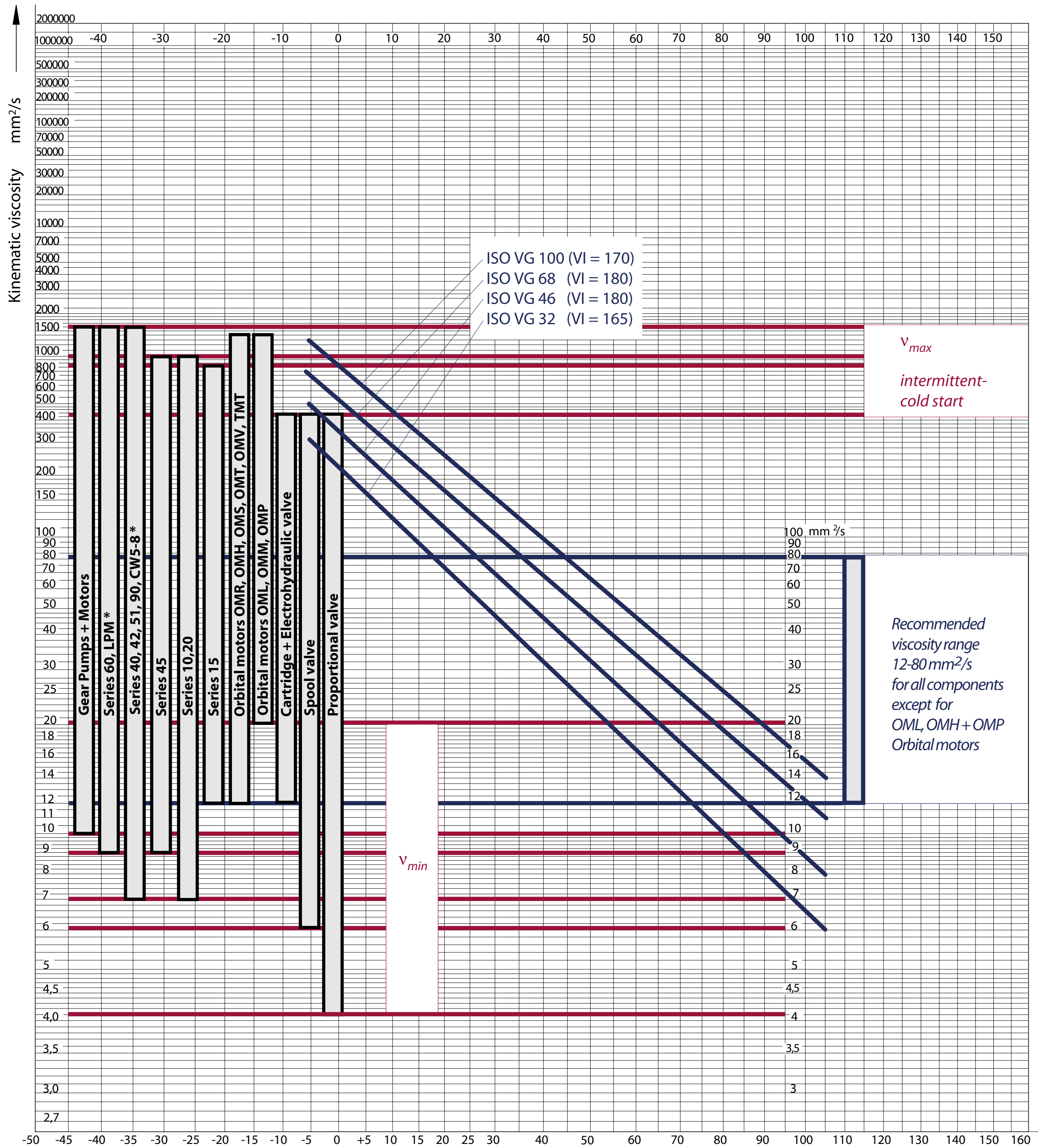


* hydrostatic motor only

P002 051E

HYDRAULIC FLUID ACCORDING DIN 51 524-3 HVLP, VISCOSITY – TEMPERATURE DIAGRAM

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



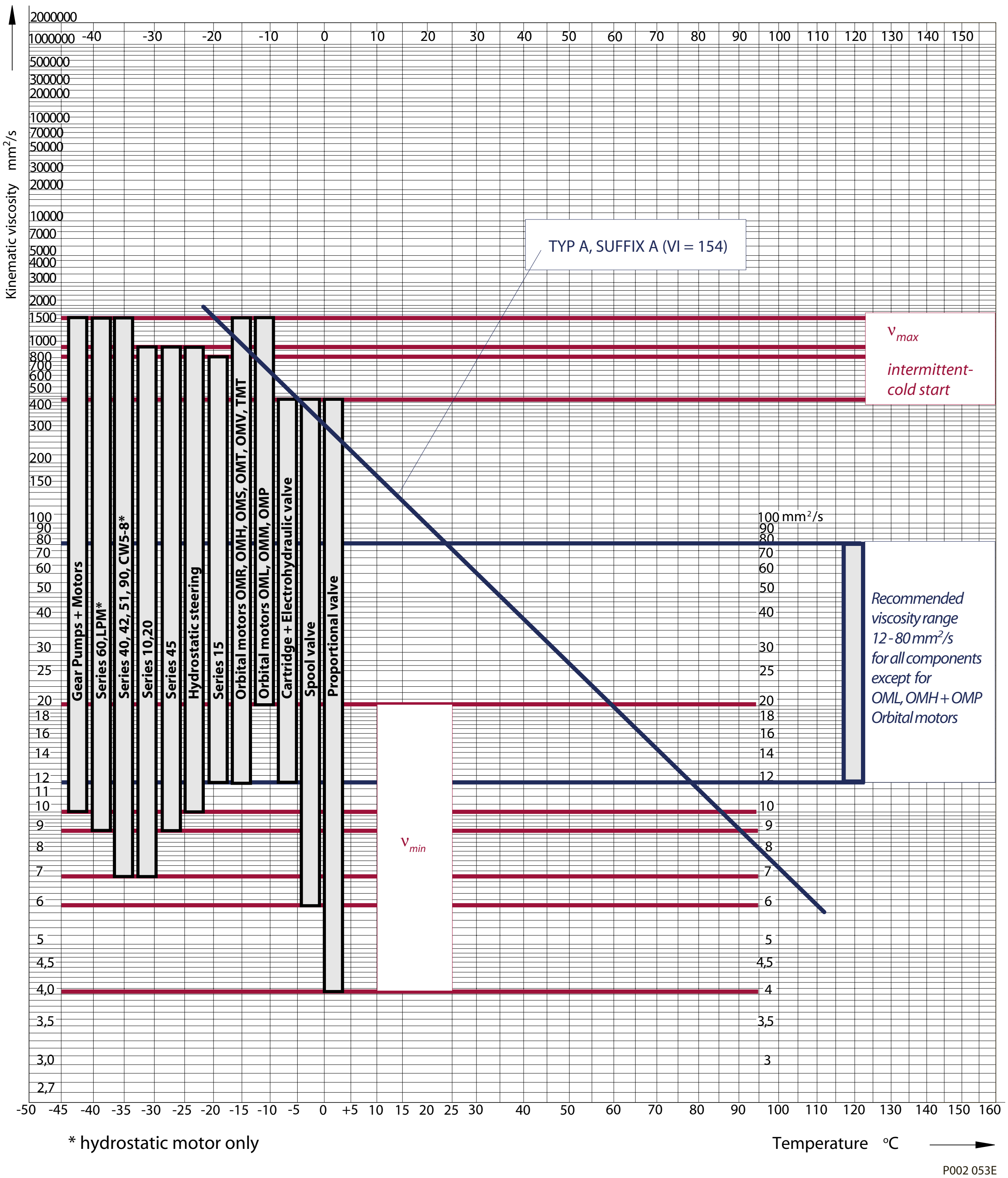
* hydrostatic motor only

Temperature °C

P002 052E

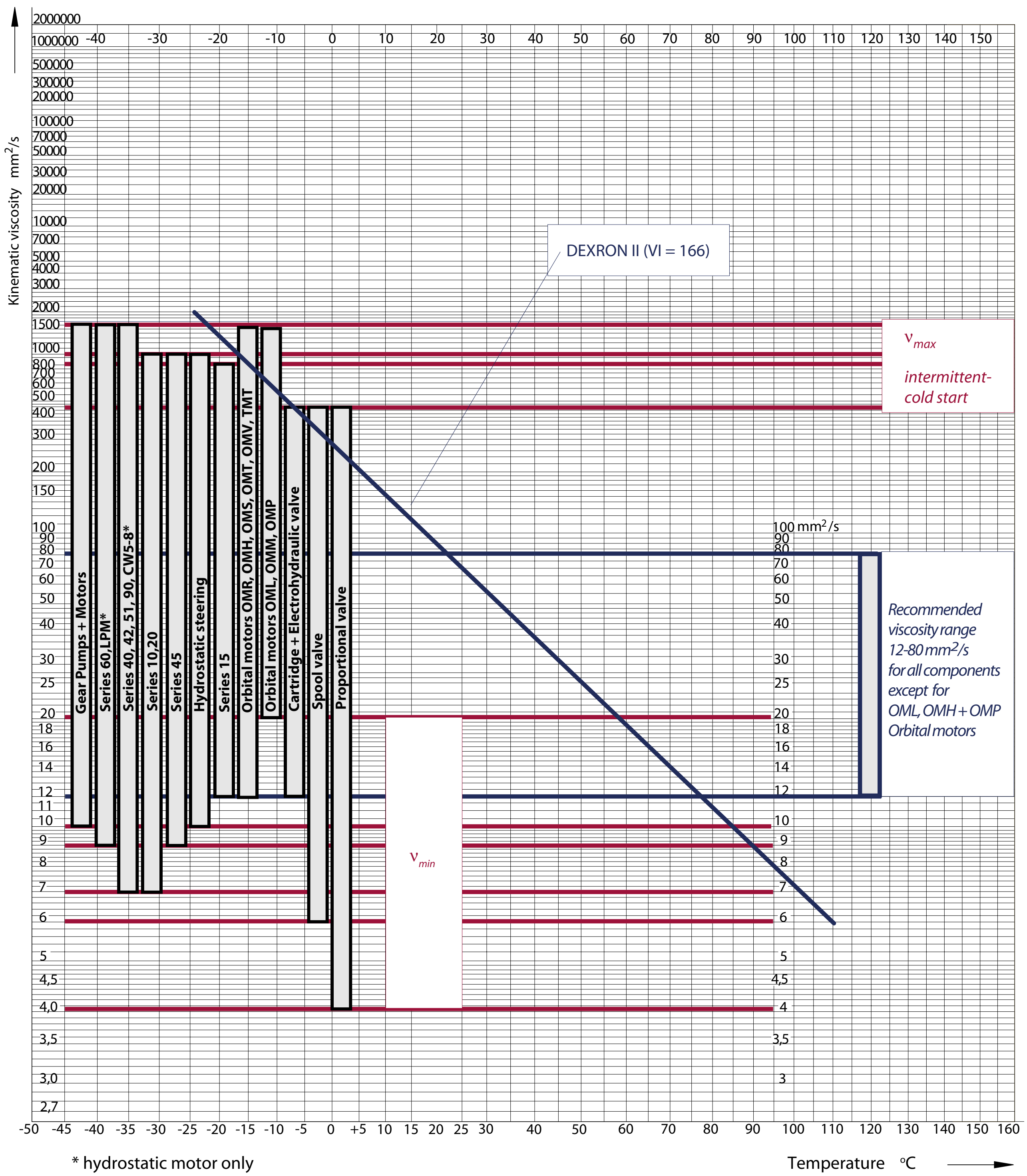
AUTOMATIC TRANSMISSION FLUIDS (ATF) TYP A SUFFIX A (GM), VISCOSITY – TEMPERATURE DIAGRAM

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



AUTOMATIC TRANSMISSION FLUIDS (ATF) DEXRON II (GM), VISCOSITY – TEMPERATURE DIAGRAM

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

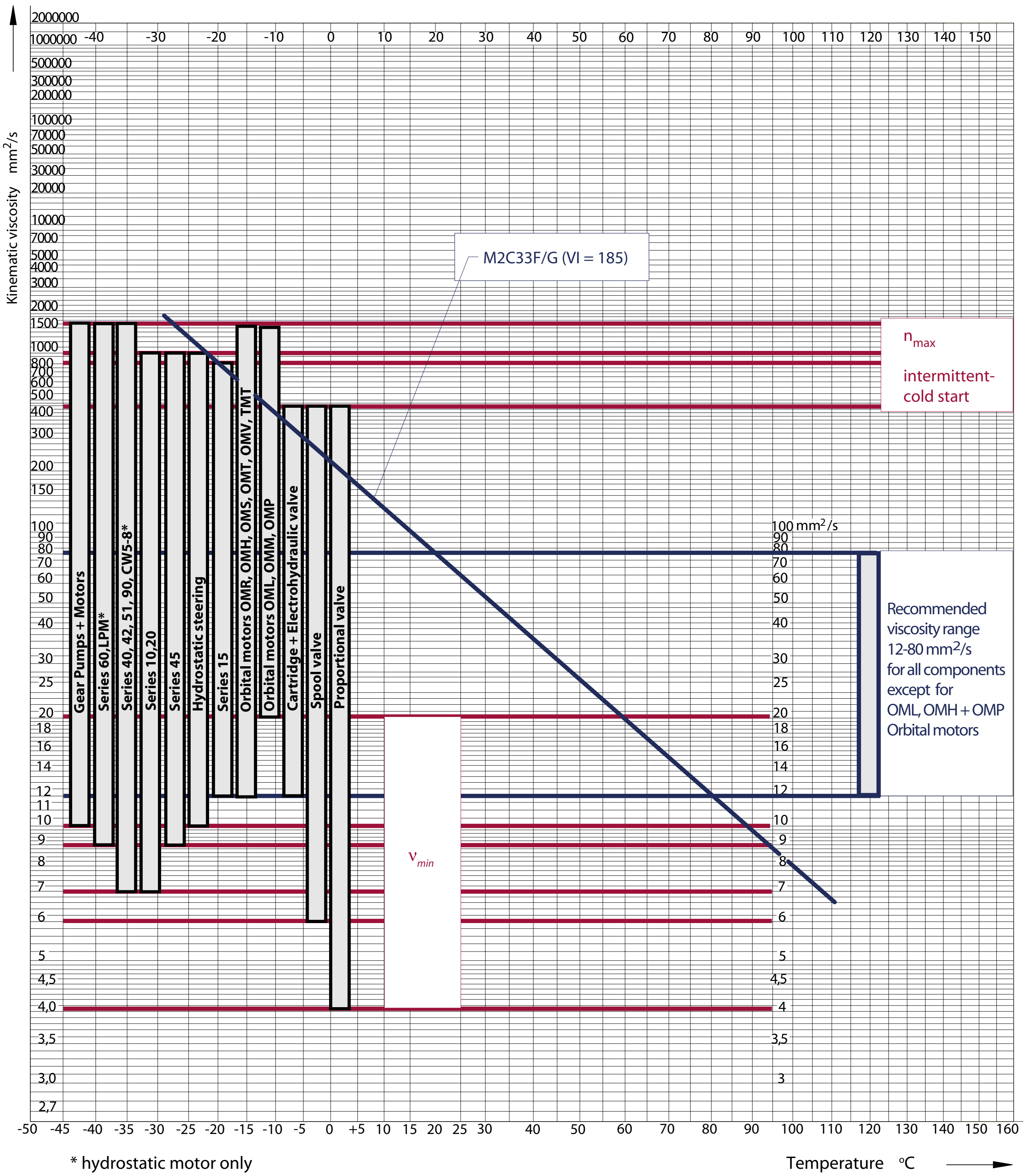


* hydrostatic motor only

P002 054E

AUTOMATIC TRANSMISSION FLUIDS (ATF) M2C33F/G, FORD, VISCOSITY – TEMPERATURE DIAGRAM

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

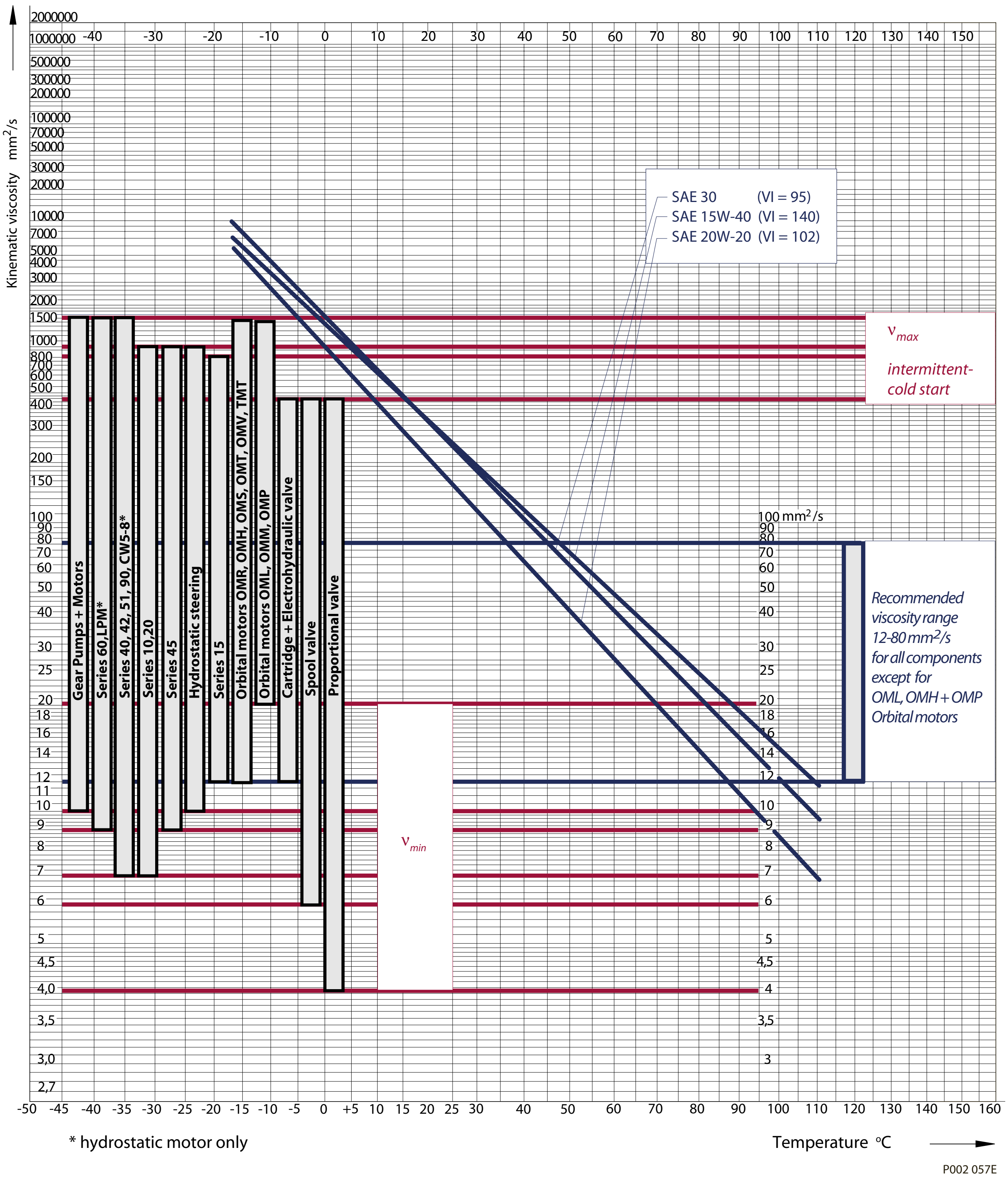


* hydrostatic motor only

P002 056E

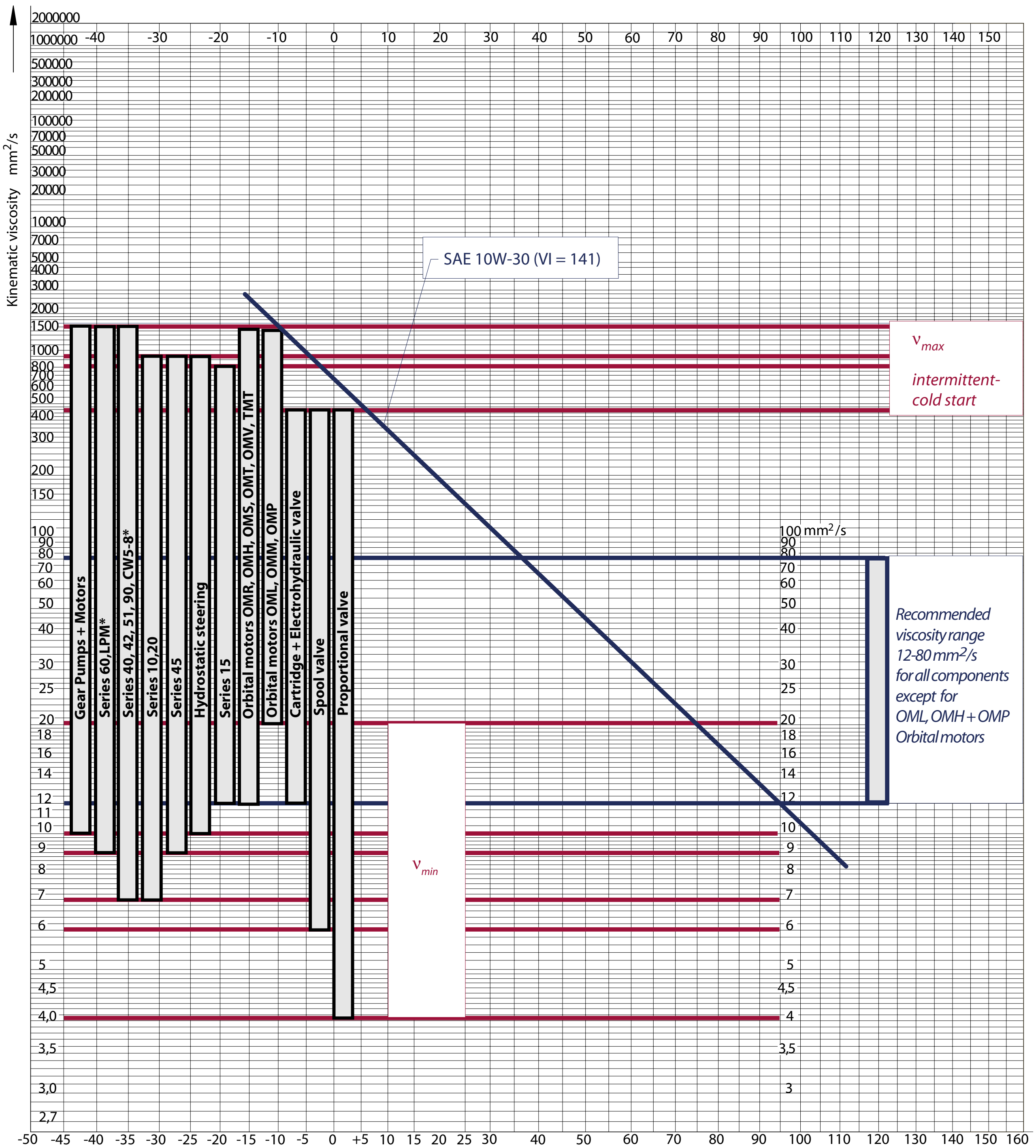
ENGINE OIL PER API CLASSIFICATION SL, SJ, CI-4, CH-4, CG-4, CF-4 AND CF, VISCOSITY – TEMPERATURE DIAGRAM

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



MULTI PURPOSE OIL STOU - SUPER TRACTOR OIL UNIVERSAL, VISCOSITY – TEMPERATURE DIAGRAM

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



* hydrostatic motor only

P002 058E

FIRE RESISTANT HYDRAULIC FLUIDS ACCORDING TO DIN 24 317, DIN 24320, VDMA 24 317, AND ISO 12 922

HFA fluids – oil-in-water emulsions according to DIN 24 320 and ISO 12 922.
There can be bacterial control problems and corrosion problems. Fluid pH stability can be a problem and can cause wear and chemical reaction with aluminium. Also, there may be a solvent action on some paints.
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** fluids are Oil-in-Water emulsions with low emulsion oil content according to DIN 24 320 and ISO 12 922. Normally these fluids contain 1 to 5 % emulsion oil related to the volume.
- **HFAS** fluids are solutions with typically not more than 10 % fluid concentrate in water according to ISO 12 922.

HFB fluids – water-in-oil emulsions according to VDMA 24 317 and 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 – watery polymer solutions or water glycols according to VDMA 24 317 and 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.

FIRE RESISTANT HYDRAULIC FLUIDS ACCORDING TO DIN 24 317, DIN 24 320, VDMA 24 317, AND ISO 12 922 (continued)

HFD fluids – water free, synthetic fluids according to VDMA 24 317 and 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.

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

HFD fluids are divided into four groups: **HFDR, HFDS, HFDT,** and **HFDU**.

- **HFDR:** Fluid based on Phosphorus acid Ester according to DIN 24 317 and ISO 12 922. Used primarily in Great Britain in the mining industry.
- **HFDS:** Fluid based on Chlorinated Hydrocarbons according to DIN 24 317. Used primarily in hydrodynamic clutches.
- **HFDT:** Fluid based on mixtures of Phosphorus acid Ester and Chlorinated Hydrocarbons according to DIN 24 317. Used primarily in hydrostatic transmissions.
- **HFDU:** Other synthetic hydraulic fluids without water according to DIN 24 317 and ISO 12 922. Used primarily in aviation hydrostatic.

Fluid conversion

Consult VDMA 24 314, 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.

REQUIREMENTS FOR FIRE RESISTANT HYDRAULIC FLUIDS

General operating parameters for fire resistant hydraulic fluids

Sauer-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 Sauer-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

	Dimension	Typ			
		HFA	**HFB**	**HFC**	**HFD**
Standard	-	ISO 12 922 DIN 24 320	ISO 12 922 VDMA 24 317		
Features	-	Oil in water emulsion	Oil in water emulsion	Watery polymer solution	Water free synthetic fluids
Operating temperature[1]	°C [°F]	5 – 55 [40 – 130]	5 – 60 [40 – 140]	-20 – 60 [-4 – 140]	10 – 70 [50 – 160]
Water content [1]	%	> 80	> 40	> 35	–
Typical roller bearing life (mineral based fluid is 100 %)	%	< 5	30 - 35	10 - 20	50 – 100

[1] The temperature range and the water content are based on the specific fluid properties.

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.

Gear pumps and gear motors:

Gear pumps and gear motors may not be operated with fire resistant fluids.

Fluid change intervals:

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

REQUIREMENTS FOR FIRE RESISTANT HYDRAULIC FLUIDS (continued)

Operating parameters

Axial piston pumps and motors, bent axis motors

<table>
<tr><th rowspan="2"></th><th rowspan="2">Dimension</th><th colspan="4">Typ</th></tr>
<tr><th>HFA</th><th>HFB</th><th>HFC</th><th>HFD</th></tr>
<tr><td>Standard</td><td>-</td><td>ISO 12 922
DIN 24 320</td><td colspan="3">ISO 12 922
VDMA 24 317</td></tr>
<tr><td>Speed</td><td>%</td><td colspan="3">65</td><td>100</td></tr>
<tr><td>Differential pressure</td><td>%</td><td>40</td><td>70</td><td>60</td><td>100</td></tr>
<tr><td>Inlet pressure</td><td>bar abs. [in Hg]</td><td>1 [0]</td><td colspan="3">0.95 [1.5]</td></tr>
</table>

Orbital motors

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="4">Typ</th></tr>
<tr><th>HFA</th><th>HFB</th><th>HFC</th><th>HFD</th></tr>
<tr><td colspan="3">Standard</td><td>ISO 12 922
DIN 24 320</td><td colspan="3">ISO 12 922
VDMA 24 317</td></tr>
<tr><td rowspan="6">Maximum differential pressure bar [psi]</td><td rowspan="2">OMM/OMP</td><td>cont.</td><td>50 [725]</td><td colspan="3">70 [1015]</td></tr>
<tr><td>interm.</td><td rowspan="2">70 [1015]</td><td colspan="3" rowspan="2">100 [1450]</td></tr>
<tr><td rowspan="2">OMR</td><td>cont.</td></tr>
<tr><td>interm.</td><td rowspan="2">100 [1450]</td><td colspan="2" rowspan="2">140 [2031]</td><td rowspan="2">170 [2466]</td></tr>
<tr><td rowspan="2">OMS/OMT/OMV</td><td>cont.</td></tr>
<tr><td>interm.</td><td>140 [2031]</td><td colspan="2">175 [2538]</td><td>210 [3046]</td></tr>
<tr><td colspan="3">Estimated life time
(mineral based fluid is 100%)</td><td>2 - 5%</td><td>10 - 20%</td><td>10 - 15%</td><td>80 - 100%</td></tr>
</table>

The above mentioned recommendations for maximum temperature limits are a guideline for most 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 ACCORDING TO VDMA 24 568 AND ISO/CD 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 VDMA 24 568 is a preliminary guideline. Several technical data have to be evaluated and specified for the use in hydrostatic transmissions by the standardization group. Therefore todays hydraulic fluids following VDMA 24 568 do not operate satisfactory under all circumstances.

A new ISO standard for biodegradable hydraulic fluids is under development:
ISO/CD 15 380, Lubricants, industrial oils and related products (class L)
- Family H (Hydraulic systems)
- Specifications for categories HETG, HEPG, HEES, and HEPR

Since long term experience is not yet available on the application of biodegradable hydraulic fluids, Sauer-Danfoss does not guarantee flawless operation of these fluids for every application.

For high performance installations we recommend thorough field testing of the fluid in questions.

In addition, the adherence to minimum requirements does not mean that the hydraulic fluid may be used without restrictions. Before using a biodegradable hydraulic fluid please see attached list of Sauer-Danfoss experience with biodegradable hydraulic fluids or contact Sauer-Danfoss.

Before changing a machine over to a new oil it is imperative to consult with the individual manufacturer of each machine.

⚠ 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.

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

BIODEGRADABLE HYDRAULIC FLUIDS ACCORDING TO VDMA 24 568 AND ISO/CD 15 380 (continued)

HETG - Triglyceride hydraulic fluids

Fluid characteristics

- 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 VDMA 24 568 are generally met.
- the minimum requirements of ISO/CD 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!

Fluid change interval:

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

Note: Before using a biodegradable hydraulic fluid please ask for list of Sauer-Danfoss experience with biodegradable hydraulic fluids.

Hints for transition

VDMA 24 569–Rapidly Biologically Degradable Hydraulic Fluids, ISO/CD 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in VDMA 24 569 and ISO/CD 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HETG

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level described in the section *Requirements of hydraulic fluids* must be met in addition to above mentioned requirements, especially the needed temperature limitations to prevent rapid fluid ageing.

BIODEGRADABLE HYDRAULIC FLUIDS ACCORDING TO VDMA 24 568 AND ISO/CD 15 380 (continued)

HEPG – Poly glycol hydraulic fluids

Fluid characteristics

- 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 VDMA 24 568 are generally met
- the minimum requirements of ISO/CD 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!

Note: Before using a biodegradable hydraulic fluid please ask for list of Sauer-Danfoss experience with biodegradable hydraulic fluids.

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.

VDMA 24 569 – Rapidly Biologically Degradable Hydraulic Fluids, ISO/CD 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in VDMA 24 569 and ISO/CD 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HEPG

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level described in the section *Requirements of hydraulic fluids* must be met in addition to above mentioned requirements.

BIODEGRADABLE HYDRAULIC FLUIDS ACCORDING TO VDMA 24 568 AND ISO/CD 15 380 (continued)

HEES – Synthetic ester based hydraulic fluids

Fluid characteristics:

- 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 VDMA 24 568 are generally met
- the minimum requirements of ISO/CD 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!

Note: Before using a biodegradable hydraulic fluid please ask for list of Sauer-Danfoss experience with biodegradable hydraulic fluids.

Hints for transition

VDMA 24 569 – Rapidly Biologically Degradable Hydraulic Fluids, ISO/CD 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in VDMA 24 569 and ISO/CD 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HEES

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level described in the section *Requirements of hydraulic fluids* must be met in addition to above mentioned requirements.

BIODEGRADABLE HYDRAULIC FLUIDS ACCORDING TO VDMA 24 568 AND ISO/CD 15 380 (continued)

HEPR – Polyalphaolefins and related hydrocarbon hydraulic fluids

Fluid characteristics

- 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 VDMA 24 568 are generally met
- the minimum requirements of ISO/CD 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!

Note: Before using a biodegradable hydraulic fluid please ask for list of Sauer-Danfoss experience with biodegradable hydraulic fluids.

Hints for transition

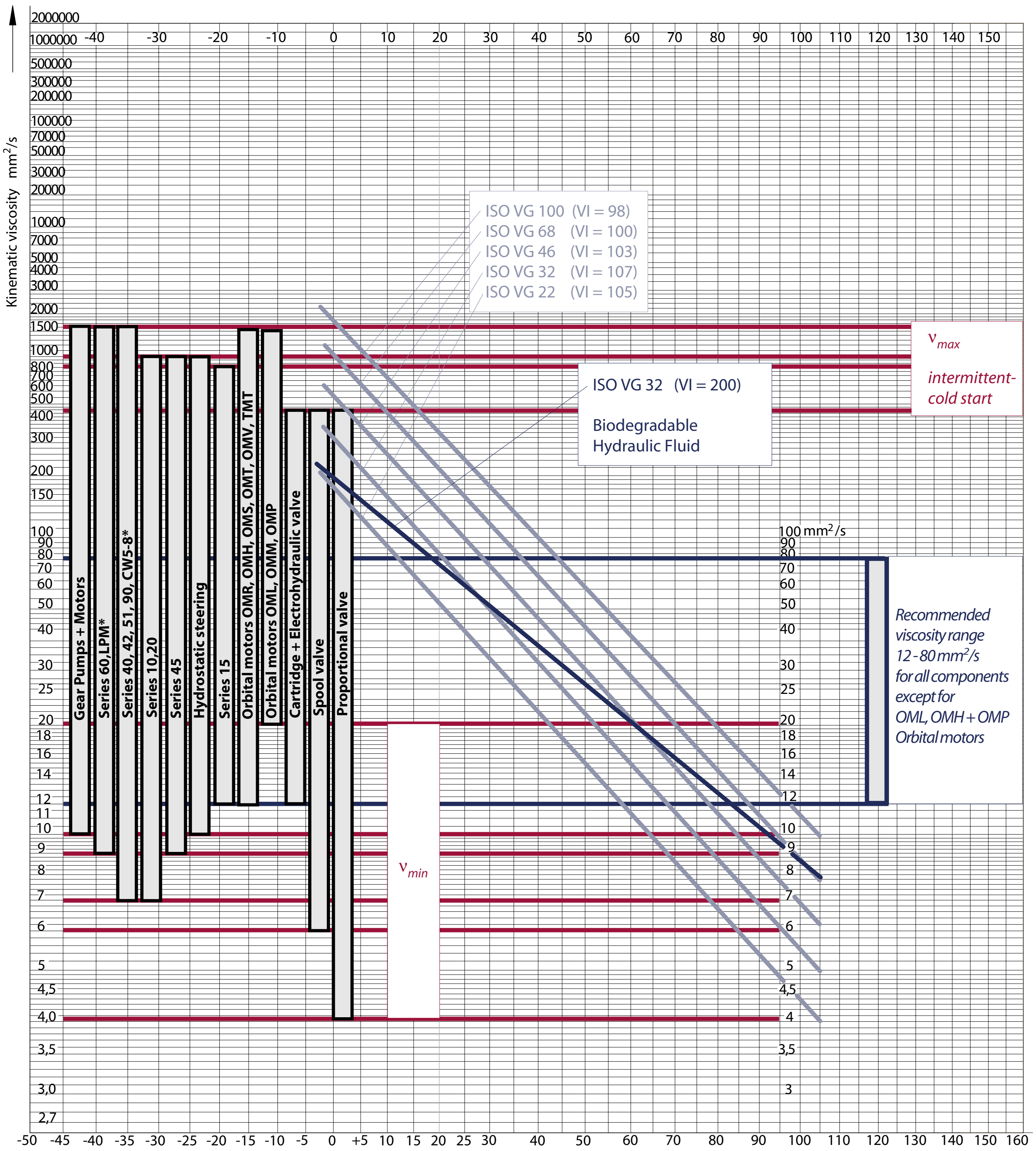
VDMA 24 569 – Rapidly Biologically Degradable Hydraulic Fluids, ISO/CD 15 380, and the appropriate guidelines of each individual hydraulic fluid manufacturer are applicable. The remaining max residual volume as specified in VDMA 24 569 and ISO/CD 15 380 must not be exceeded.

Requirements for biodegradable hydraulic fluids HEPR

The requirements concerning water content, Viscosity–Temperature limits, cleanliness level described in the section *Requirements of hydraulic fluids* must be met in addition to above mentioned requirements.

BIODEGRADABLE HYDRAULIC FLUIDS, VISCOSITY – TEMPERATURE DIAGRAM

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



*hydrostatic motor only

P001 678E

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.*

TECHNICAL REQUIREMENTS

Viscosity limits

When selecting a lubricating fluid the viscosity limits in the table are to be observed.

Guidelines for lubricating fluid selection based on mineral oil with respect to the mechanical gear box type

<table>
<tr><th colspan="6">Viscosity limits</th></tr>
<tr><th></th><th>Min. Viscosity (intermittent) mm²/s [SUS]</th><th>Max. Temp. °C [°F]</th><th>Recommended viscosity range mm²/s [SUS]</th><th>Cold start viscosity mm²/s [SUS]</th><th>Min. Temp. °C [°F]</th></tr>
<tr><td>RMF</td><td>30 [141]</td><td>95 [203]</td><td>40 - 2000 [186 -9260]</td><td rowspan="6">20 000 [926 000]</td><td rowspan="4">-40 [-40]</td></tr>
<tr><td>PVG</td><td>12 [66]</td><td>110 [230]</td><td>16 - 800 [81 - 3700]</td></tr>
<tr><td>CW 5-8</td><td rowspan="3">25 [119]</td><td>95 [203]</td><td rowspan="3">40 - 2000 [186 - 9260]</td></tr>
<tr><td>CW12-18 / CT18-35</td><td>90 [194]</td></tr>
<tr><td>CR 31-51</td><td>100 [230]</td><td>-30 [-22]</td></tr>
<tr><td>TMG</td><td>30 [141]</td><td>85 [185]</td><td>50 - 2000 [232 - 9620]</td><td>-20 [-4]</td></tr>
</table>

SUITABLE GEAR LUBRICANTS

General

The lubricants are to be chosen together with the gear manufacturer for each application.

Sauer-Danfoss gearboxes may be operated with a variety of lubricants.

The following are suitable:

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

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage.
The rated data which we publish in our Technical Information and Service Manuals are based on the use of premium lubricants containing oxidation, rust, and foam inhibitors.

It is not permissible to mix lubricants. The different additive package may cause negative interactions.

If lubricants mixing can not be avoided, fluid manufacturers approval is required.

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage which result from mixing.

GEAR LUBRICANT APPLICATION

Example for selecting the kinematic viscosity

See also *the Nomograph on the next page.*
Example: Transit Mixer Drive (agitate mode)

a)	assumed:	**1**	Power	15 kW [20 hp]
		2	Output speed	4 min^{-1} (rpm)
		3	Gear ratio	i = 99
		-	Temperature	55 °C [131 °F]
b)	Nomograph:			
		5	required viscosity at operating temperature	180 mm^2/s [833.3 SUS]
c)	Viscosity–temperature diagram			
		-	required lubricant	CLP 460

⚠ Warning

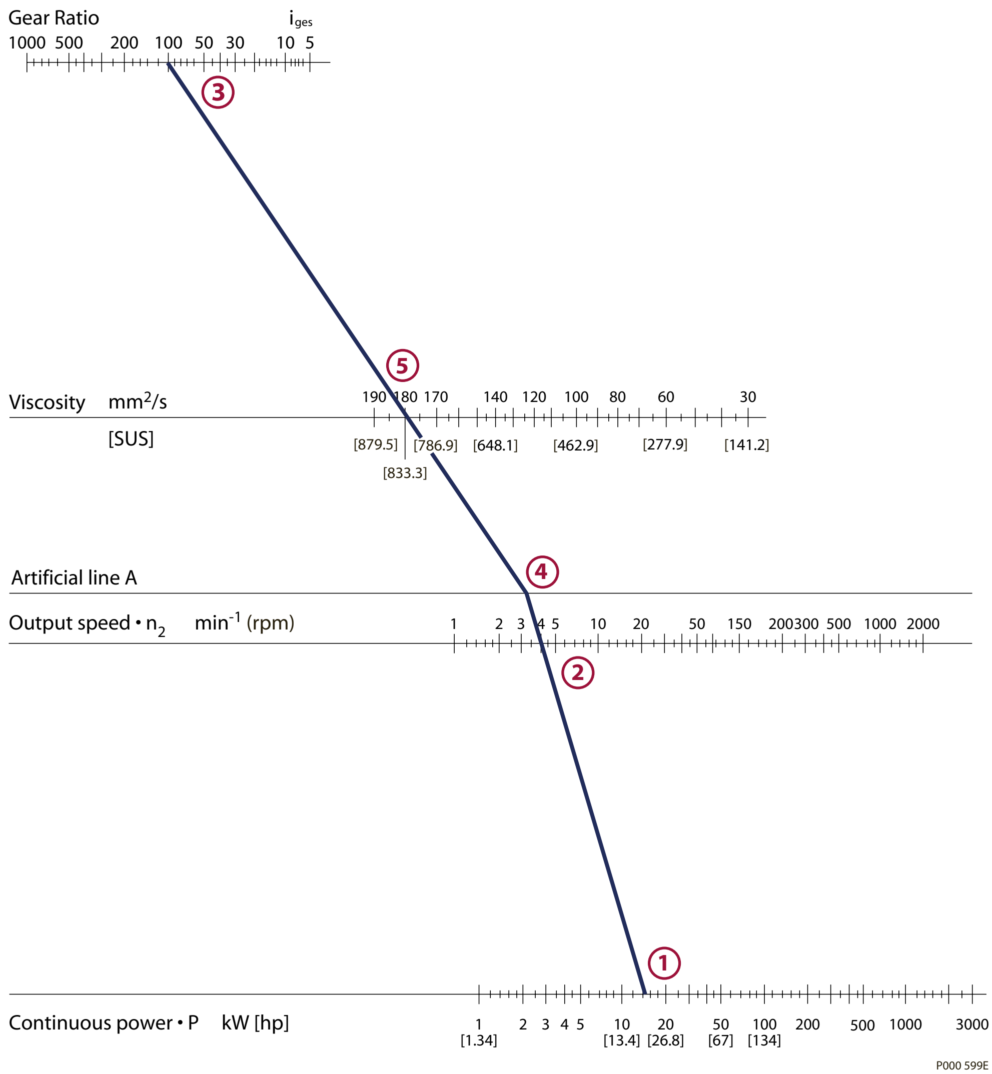
Determination of the viscosity is only a reference value.

If the viscosity is between two different ISO Viscosity grades, use the closests grade.
For a further information and selection of a lubricant, please contact your local Sauer-Danfoss representative.

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 are suitable. At higher temperatures we recommend Gear Lubricants with SAE-Viscosity grade 140.

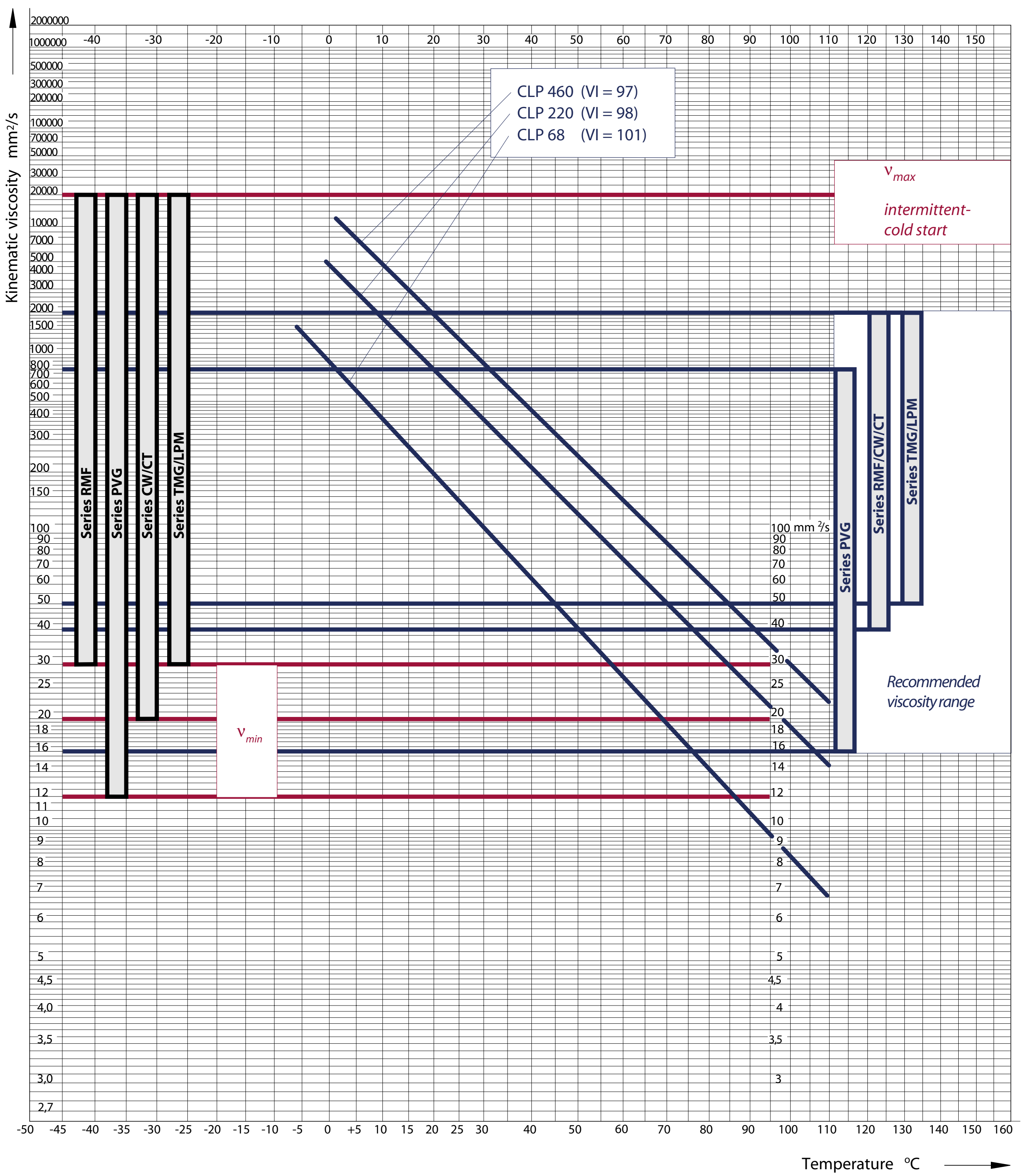
GEAR LUBRICANT APPLICATION (continued)(

Nomograph for selection of kinematic viscosity for gear lubricants



SUITABLE GEAR LUBRICANTS

Lubricants according to DIN 51 517-3 - CLP, Viscosity–temperature diagram



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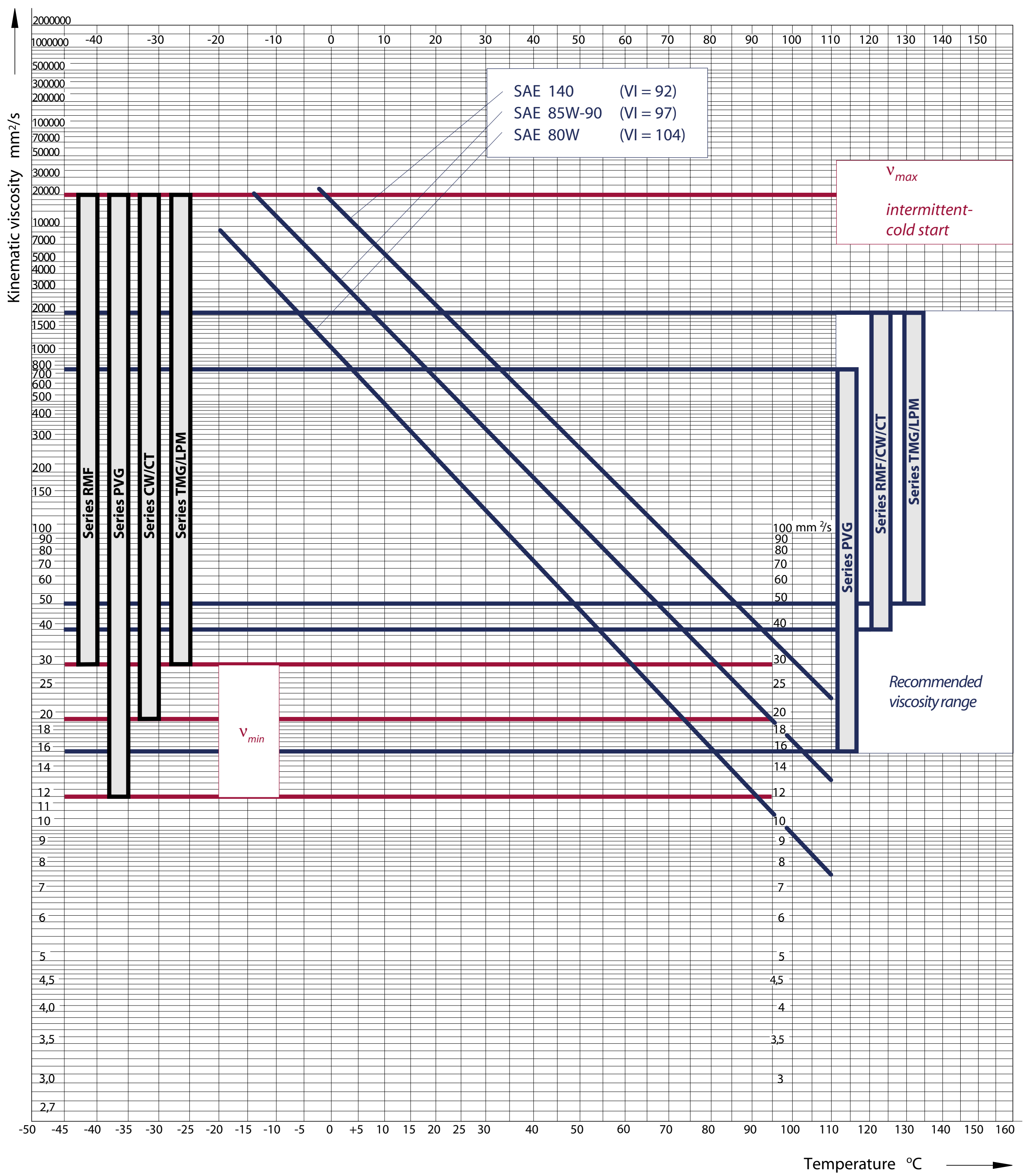
SUITABLE GEAR LUBRICANTS

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



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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 (DIN ISO 2176)

The dropping point of a bearing grease is the temperature at which the first drop of grease brought to melting falls from a DIN-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.

FEATURES (continued)

Consistency

The consistency index indicates how firm or soft a grease is.
The following table provides a good survey.

Bearing grease, worked penetration

Consistency index NGLI-grade per DIN 51 818	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

SUITABLE GEAR BEARING GREASE

The gear bearing grease is to be choosen together with the gear manufacturer for the application in question.

The following grease is suitable – **Grease DIN 51 825.**

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage.
The rated data which we publish in our Technical Informations and Service Manuals are based on the use of premium lubricants containing oxidation, rust, and foam inhibitors.

It is not permissible to mix lubricants. The different additive package may cause negative interactions. If lubricants mixing can not be avoided, fluid manufacturers approval is required.

The Sauer-Danfoss warranty claim policies do not apply for fluid related damage which result from mixing.

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.

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.

Preservation measures

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

* see table below

APPLICATION OF PRESERVATION FLUIDS (continued)

Preservation measure code

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

FEATURES / 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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Cartridge valves

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