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Brueninghaus Hydromatik

# Hydraulic Fluids on a Mineral Oil Basis for Axial Piston Units

RE 90220/12.95

replaces 03.88

## General

In order to guarantee trouble-free and efficient operation, the hydraulic fluid in a hydrostatic system should be selected carefully according to the following points in mind during the design of the system. If all requirements cannot be met, i.e. for reasons of price, each application must be considered individually.

## Energy Transfer

All mineral oils (even those containing air) transfer energy and pressures quickly (by means of high velocity sound ⓐ) although this is cushioned by the favourable damping factor ⓑ. Large volumes of oil, hoses and undissolved gases (in accumulators) also decrease system stiffness.

The question as to whether to employ a system which is stiff and which will transmit forces accurately but which will put heavy stresses on materials, or to use a soft system which yields and protects materials but which may also lead to oscillations occurring, is not normally decided from the physical data of the fluid.

**The compressibility of the installation must be considered and suitable steps taken to accommodate it.**

## Dynamic Attidude

The viscosity ① or viscosity-temperature ratio ⓒ (viscosity index) are of primary importance as are the viscosity-pressure relationship ⓓ, the density ② and the pour point ⑥.

Higher viscosities (thicker oils) deteriorate the mechanical-hydraulic efficiency. The leakage losses are instead smaller.

The following adverse results are:

When the pressure is low, bearing clearances are not fully filled causing considerable wear to occur. On the suction side, filling losses occur which cause cavitation damage due to implosion occurring.

If the viscosity is too low, higher leakages will occur and thinner oil films lead to higher bearing wear.

In contrast to water, the viscosity of mineral oils falls with rising temperature (dependent upon the viscosity index) ⓒ. This makes selection of fluid difficult.

Dependent upon the application, the following criteria must also be taken into consideration:

The design of the hydraulic pumps and motors:

In conjunction to the normal EP additives in the oil, the close tolerances to which our units are manufactured permit very low viscosity fluids to be used.

The type of installation and the duty it must perform:

Friction losses in the pipelines, natural heat dissipation and additional cooling output interact with the operating data.

Viscosity is always measured at normal pressure (atmospheric pressure). In the high pressure range, the viscosity-pressure relationship leads to increased viscosity (double at 400 bar), which must be taken into consideration.

For a short time while starting, a high viscosity is permissible. This must be low enough to prevent damage to the unit.

Depending on the product resp. the sizes the following max. values are valid:

**I**: $\nu_{start} \leq 1600$ mm²/s, at min. perm. temperature of $t_{min} = -40°$ C,

**II**: $\nu_{start} \leq 1000$ mm²/s, at min. perm. temperature of $t_{min} = -25°$ C.

(see selection diagram, page 3)

In the operating range a fully functional operating viscosity must be guaranteed at 100% duty.

$$\nu_{operating} = 16 \ldots 100 \text{ mm}^2/\text{s}$$

The optimum operating range gives the highest degree of efficiency and economy at:

$$\nu_{opt} = 16 \ldots 36 \text{ mm}^2/\text{s}.$$

For this reason, systems with high operating pressures require higher viscosity and systems with large flows lower viscosity. In certain cases the viscosity has to be chosen on an overall loading pattern.

In addition, marginal lubrication limits the lower permissible viscosity depending on the product resp. the sizes to (short term):

**I**: $\nu_{min} \geq 5$ mm²/s, at max. perm. temperature of $t_{max} = +115°$ C

**II**: $\nu_{min} \geq 10$ mm²/s, at max. perm. temperature of $t_{max} = +90°$ C

(see selection diagram, page 3).

In order to simplify selection, different viscosity grades have been created. The identifying code relates to average viscosity in mm²/s at 40° C ⑤. Viscosity grades (VG) 22 to 100 are in most common use.

| | | |
|---|---|---|
| VG 22 | (A): | for **a**rctic conditions or for extremely long pipelines |
| VG 32 | (W): | for **w**inter conditions in Central Europe |
| VG 46 | (S): | for **s**ummer conditions in Central Europe or for enclosed areas |
| VG 68 | (T): | for **t**ropical conditions or for areas with high temperatures |
| VG 100 | (U): | for excessively high temperatures |

Hydraulic oils with a higher viscosity index (VI>140) so-called HVLP fluids ④ and multi grade engine oils are particularly suitable for larger temperature ranges (mobile applications). Mixing viscosities are possible, but please consult us.

For very low ambient temperatures, the pour point ⑥ must also be given consideration.

**Selection of viscosity grade is made on the basis of starting viscosity with ambient temperature (consider pour point where necessary) and optimum operating viscosity according to system and operating data (collective load) see page 3.**

## Wear Reduction

Pressure-wear relationship is generally determined by FZG test ⑦ (pressure ratings 0-3) and in special cases by a pump test. Pressure grading is according to DIN nominal pressures ⑧.

| |
|---|
| Pressure rating 0<br>Nominal pressure 80-125 bar, damage force rating zero or < 5. |
| Pressure rating 1<br>Nominal pressure 125-200 bar, damage force rating 5 - 6. |
| Pressure rating 2<br>Nominal pressure 200-250 bar, damage force rating 7 - 9 |
| Pressure rating 3<br>Nominal pressure 250-300 bar, damage force rating 10 |

Peak pressure is pressure x 1,25.

Pressure ratings 1 and 2 correspond to HL fluids.

Pressure rating 3 corresponds to HLP fluids ④.

**AIR**

When commissioning the system, it must be ensured that no air pockets remain. All fluid is saturated with air dependent upon its normal pressure ⓔ.

When subject to negative pressure, this air is released, or further air sucked in via leakage points. Cavitation (implosion of the bubbles) can occur in the negative pressure zone, and loss of compression (and explosion of the air oil mixture i.e. diesel effect) in the high pressure zone. The effect is erosion of material.

Suitable tank design, with de-aerating valves can gradually reduce this air content. A good air separation characteristic (LAV) ⑨ thicker fluids are naturally poorer - is a prime requirement. Anti foam additives only prevent surface foam and reduce air separation by allowing small bubbles to remain.

**Prevent erosion damage by means of de-aerating valves.**

## Filtration

The finer the filtration the better the achieved purity grade of the pressure fluid and the longer the life of the axial piston unit. To ensure the functioning of the axial piston unit a minimum purity grade of:

9 to NAS 1638
6 to SAE
18/15 to ISO/DIS 4406 is necessary.

In this case we recommend, depending on system and application

filter element $\beta_{20} \geq 100$.

With the rising differential pressure at the filter element the β-value must **not** decrease.

At very high temperatures of the hydraulic fluid (90°C to max. 115°C) at least cleanless class

8 to NAS 1638
5 to SAE
17/14 to ISO/DIS 4406 is necessary.

## Interaction with System Components

**CORROSION**

Anti-corrosion additives protect ⑩ the components during storage or operation from condensation or water from leaking coolers. Corrosion is intensified due to acid formation resulting from oxidisation processes (diesel effect). Mineral oils without these corrosion inhibitors do not offer satisfactory protection. On large systems which are continuously monitored, it is of advantage to use demulsifying oil with good water eliminating characteristics ⑪ . Water can be drained from the sump.

On smaller systems (mobile applications, for example) where monitoring is infrequent, emulsifying oil with additives (e.g. engine oil) is more suitable.

**Only use oils with corrosion protection.**

**SEALS**

Changes in hardness or volume ⑫ should be kept to a minimum by selecting compatible of fluid .

At temperatures above 80° C **FPM** seals (specially for the shaft seal) are recommended.

**Compatibility with the seal material must be considered.**

## Operating Conditions and Aging of Fluid

Increases of the acid level (neutralisation number) ⑬ and polymerisation (resinification ⑭, clogging of filters and throttles) results mainly from the diesel effect. An exact indication of aging may be determined for example by comparing the neutralisation number, viscosity and colour number. A further possibility is to determine the additive reserve (EP additives).

The best quality basic refined oil gives a good starting point. It is, however, necessary to add oxidisation inhibitors to the oil.

Operating temperatures over 80°C reduce the service life by half for every 10°C temperature increase, and should therefore be avoided. Operating of 4000 to 8000 hours dependent upon the type of unit ( based on 200 bar) can easily be achieved for units with a recycling time ⓕ for the oil content of at least 1 minute and good filing and bleed characteristics.

For applications with little oil volumes, e.g. mobile applications, the first oil change must be carried out after 300-500 hours.

With large oil volumes, e.g. in industrial applications, a regular survey of the oil as well as an exchange of oil in case of need has to be effected.

## Selection of Fluids

All mineral oil based fluids are suitable to a greater or lesser degree for applications with axial piston units. Their basic classification of application results from what has already been said due to the water, viscosity and temperature relationships, with consideration of oxidisation and corrosion protection, material compatibility, air and water separation characteristics.

**Fluid Classification:**

**Standard:**

- Fluids types HLP and HVLP to DIN 51524, parts 2 and 3 ④
- HD engine oils to API-SF or CD resp. MIL-L-2104 C and MIL-L-46152 B
- ATF fluids ⑮

**Special fluids:**

- Aviation fluids ⑯
- Marine fluids ⑰
- Lubricating oils ⑱

**Environmentally acceptable hydraulic fluids HETG, HEPG, HEES for axial piston units see RE 90221.**

**Axial piston units for use with HF-fluids see RE 90223.**

The following fluids are particularly suitable for mobile applications:
Multi-grade oils (hydraulic and engine oils),
HLP oils with detergent properties,
ATF fluids.

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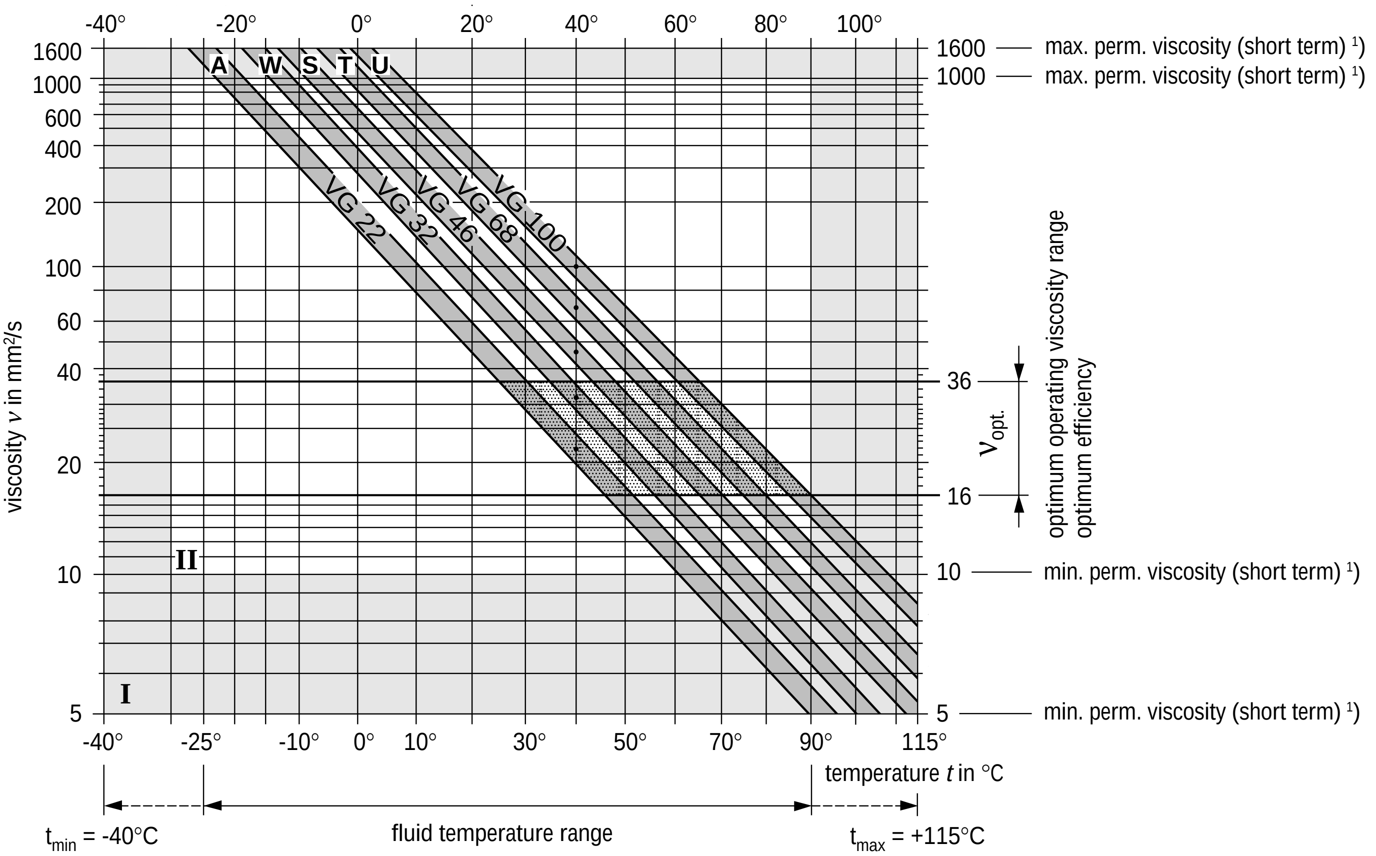
## Selection Diagram

**A** = for arctic conditions or for extremely long pipelines
**W** = for winter conditions in Central Europe
**S** = for summer conditions in Central Europe or for enclosed areas
**T** = for tropical conditions or for areas with high temperatures
**U** = for excessively high temperatures (e.g. due to internal combustion engines)




1) Depending on the product resp. the sizes the following viscosity ranges are valid:
**I** : 5 mm²/s ($t_{max}$ = +115° C) … 1600 mm²/s ( $t_{min}$ = - 40° C),
**II**: 10 mm²/s ($t_{max}$ = +90° C) … 1000 mm²/s ( $t_{min}$ = - 25° C)
(Please find the max. permissible viscosity range in the catalogue sheets of the singular products)

## Physical Formulae

ⓐ Velocity of sound in mineral oil $c = 1320$ m/s

ⓑ Compressibility factor β (Bulk modulus)

$$\beta = \frac{\Delta V}{V \cdot \Delta p} = 3 \text{ to } 8 \cdot 10^{-5} \frac{1}{\text{bar}}$$

ⓒ Viscosity-temperature characteristic

Gradient $n = \frac{U1 - U2}{2{,}303\,(\lg T2 - \lg T1)}$ where $U = ar\,sinh\,ln\,\nu$

Viscosity index VI (Calculation to DIN ISO 2909)

ⓓ Viscosity-pressure characteristic (dynamic viscosity η)

$\eta_p = \eta_o \cdot e^{\alpha \cdot p}$ ($p$ in bar) mPa • s

$\alpha_{20°C} = 0{,}00240$ bar$^{-1}$

$\alpha_{50°C} = 0{,}00205$ bar$^{-1}$

$\alpha_{100°C} = 0{,}00147$ bar$^{-1}$

(after: “Druckflüssigkeiten” (Fluids)
by Dipl. Ing. Horst Dietterle, The Shell Organisation)

ⓔ Bunsen-Coefficient for air in mineral oil ≈ 0,09

$$V_L \approx 0{,}09 \cdot V_{Öl} \cdot \frac{p_2}{p_1}$$

$V_L$ = Volume of air dissolved in oil in cm$^3$

$V_{Öl}$ = Oil volume in cm$^3$

$p_2$ = Final pressure in bar

$p_1$ = Start pressure in bar

ⓕ Recycling ratio

$$i = \frac{q_V}{V_{system}} \quad \text{min}^{-1}$$

This is the reciprocal of the recycling time

$q_V$ in L/min (pump flow)

$V$ in L (oil content of the system)

## Measuring Techniques and Standards

| | | |
|---|---|---|
| ① | Kinematic viscosity in mm$^2$/s<br>Typically measured with an<br>"Ubbelohde" viscosity meter to | DIN 51562 |
| ② | Density at 15° C in g/cm$^3$<br>with an areometer to | DIN 51757 |
| ③ | Viscosity index (VI) | DIN ISO 2909 |
| ④ | For HLP-fluids<br>For HVLP-fluids | DIN 51524 part 2<br>DIN 51524 part 3 |
| ⑤ | Viscosity classification (to ISO) | DIN 51519 |
| ⑥ | Pourpoint (on attaining liquid limit,<br>at 3° higher than solidifying point) | DIN ISO 3016 |
| ⑦ | FZG standard test A/8, 3/90<br>(Gears loaded in 12 stages<br>at 90° C starting temperature<br>and 8,3 m/s circumferential speed) | DIN 51354 part 2 |
| ⑧ | Pressures - terms - ratings | DIN 24312 |
| ⑨ | Air elimation characteristic | DIN 51381 |
| ⑩ | Corrosion protection of steel<br>(process A)<br>Corrosion protection of copper | <br>DIN 51585<br>DIN 51759 |
| ⑪ | Demulsifying characteristics<br>Water content | DIN 51599<br>DIN ISO 3733 |
| ⑫ | Compatibility with seal materials<br>in combination with<br>and | DIN 53538 part 1<br>DIN 53521<br>DIN 53505 |
| ⑬ | Neutralisation number in $\frac{\text{mg KOH}}{\text{g}}$ | DIN 51558 part 1 |
| ⑭ | Conradson test | DIN 51551 |
| ⑮ | ATF (Automatic-Transmission-Fluid) | AQ A Suffix A |
| ⑯ | Aviation fluids | MIL-H-5606 A<br>Nato-H-515 |
| ⑰ | Marine fluids | Nato-H-540 |
| ⑱ | Lubricating oils | DIN 51517 sheet 3 |

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