General
The hydraulic fluid is an important component of any operating hydraulic systems. The fluid covers several tasks:
• Power transmission
• Wear protection resp. wear reduction
• Heat transfer.

The importance of the fluid may be seen in the following statement: “Statistical data indicate, that more than 80% of all failures of hydraulic components are causal related to an improper condition of the hydraulic fluid.

The selection and the maintenance and/or control of the fluid for a hydraulic system is of major importance. The main criteria for this selection are given in the following.

Power transmission
An important index for the power transmission behavior of a hydraulic fluid is the bulk module $E_{oil}$, measured in bar. It describes, how much the volume of a fluid content is reduced under pressure.

A „hard“ hydraulic fluid (high bulk module) transmits pressures very fast and leads to a stiff hydraulic system. This is appreciated in closed loop controlled systems. „Stiff“ systems are achieved by small pressurized volumes, hard surrounding walls (pipes instead of flexible hoses) and high viscose fluids. Beside that pressure increases the bulk module of mineral oil.

A „soft“ hydraulic system is more subject to instability, but it is in general quieter, because high frequent pressure ripple is damped better.

The air content of a fluid plays an important role. Mineral oil contains some 9% air in solution under atmospheric pressure. If caused by under pressure in a hydraulic circuit (pump inlet, high fluid velocity in orifices or by turbulences due to high return line speed into the reservoir), part of this air occurs as bubbles, the systems stiffness is drastically reduced, which can cause several problems. The viscosity of the hydraulic fluid has a high influence on the dynamic power transmission. A high viscosity, that means a „thick“ fluid, leads to a worse fluidity and that means:

- Higher pressure losses in pipes and components
- Reduction of hydraulic-mechanic efficiency,
- More pressure drop in suction line, filling losses, cavitation
- Sealing and lubrication gaps are not getting fully filled, loss of lubrication.

A too low viscosity leads to the following problems:
- Higher leakage across all sealing gaps in the pump and in valves
- Thinner lubrication film causes more direct metal-to-metal contact and more wear in glide and roller bearings.

For these reasons the selection of the right viscosity and the best viscosities-temperature index needs highest attention. Some of the selection criterias are:
- Function principle of hydraulic pumps and motors used in the system
- Nominal pressure, nominal temperature (and range)
- Environmental temperature (and range)
- Length of piping.

The following limits are to be considered:
- Optimum working viscosity regarding efficiency, economy and safety
  \[ v_{opt} = 20 – 40 \text{ mm}^2/\text{s} \]
- Working viscosity for full operability
  \[ v_{operation} = 16 – 100 \text{ mm}^2/\text{s} \]
- Viscosity limits for reduced operating conditions (speed of rotation, pressure, load cycle)
  \[ v_{limit} = 12 – 300 \text{ mm}^2/\text{s} \]
- Lowest viscosity limit, start of the damaging metal-to-metal contact, only for short time and max. 50% nominal pressure
  \[ v_{min} = 8 \text{ mm}^2/\text{s} \]
- Highest start up viscosity, suction limit of pumps, only for short time when suction line is short and straight
  \[ v_{Start} = 800 \text{ mm}^2/\text{s} \]
- The recommended temperature range (fluid temperature) for the operation of a hydraulic system is between 30°C and 70°C, -30°C as the lowest and +90°C as the highest limit never should be exceeded depending on a fluid capable of these temperatures.
Mineral oil is offered in different viscosity classes (VG, viscosity grade). The characteristic number describes the nominal viscosity in mm²/s at 40°C:

- VG 22  arctic conditions, extremely long pipes;
- VG 32  wintery conditions;
- VG 46  normal conditions, closed buildings;
- VG 68  tropical conditions.

The correlation between viscosity and temperature usually is described in the double logarithmic Ubbelohde diagram.
Wear Protection resp. Wear Reduction

In hydraulic components there are many gliding contacts partly under high (side) loads. Beside the correct viscosity, which on one hand is responsible for the required supply of lubricating fluid to the gap, on the other hand assures a stable lubricating film, the wear reduction capability of the hydraulic fluid is of major importance.

The describing parameter, the „Schadenskraftstufe“ (load carrying capability), is determined in the FZG-normal test A/8.3/90 according to DIN 51 354 part 2 (gear transmission test rig, 12 defined load steps at 90°C start temperature and 8.3 m/s circumferance speed). Depending on the nominal working pressure the following „Schadenskraftstufe“ is recommended:

<table>
<thead>
<tr>
<th>nominal pressure [bar]</th>
<th>&quot;Schadenskraftstufe&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 – 125</td>
<td>≥ 5</td>
</tr>
<tr>
<td>125 – 200</td>
<td>5 – 6</td>
</tr>
<tr>
<td>200 – 250</td>
<td>7 – 9</td>
</tr>
<tr>
<td>250 – 320</td>
<td>≥ 10</td>
</tr>
<tr>
<td>&gt; 320</td>
<td>≥ 12</td>
</tr>
</tbody>
</table>

Max pressure limit: 1.25 x nominal pressure

Mineral oils are offered according to DIN 51 524 in different fluid types:

- HL-fluids according to DIN 51 524 part 2, normal working load conditions, „Schadenskraftstufe“ 6 – 10
- HLP-fluids according to DIN 51 524 part 3, higher working load conditions, „Schadenskraftstufe“ > 10

Modern HLP-fluids today usually come with a „Schadenskraftstufe“ >12. They are equipped with wear prohibiting additives, which ensure a high safety of operation even under severe working conditions.

Beside the wear reduction due to the elasto-hydrodynamic properties of the hydraulic fluid, which are expressed in the FZG value, the behavior of the fluid in a mixed friction situation is very important for the use of a fluid in heavy duty hydraulic applications. In hydraulic components mixed friction occurs permanently, because the velocity difference between two components in contact very often is below the minimum velocity for hydrodynamic lubrication.

During mixed friction, i.e.: at a direct metal-to-metal contact between two surfaces, the "lubricity" of a fluid is most important. The lubricity is measured according to DIN 51 347 and is expressed as a specific load in N/mm², at which wear does not yet occur. This value sometimes also is called the “Brugger-value”.

It is measured in a test device, which moves two cylindrical test elements under a defined load. On one of the test elements a wear mark is created. This wear mark grows during the first seconds of the test, but then stays for several minutes at a constant size. The size of this wear mark gives a reading for the specific "wear free" load for this particular fluid in N/mm².

For general applications this value has to be at least 30 N/mm², measured in accordance to DIN 51 347-2.

For heavily loaded hydraulic equipment and fast cycling machines and/or high dynamic loads this value should not be below 50 N/mm², measured in accordance to DIN 51 347-2.

But a fluid can maintain its wear prohibiting capabilities only, when it is not contaminated with hard and aggressive particles. Therefore in the interest of a long functional life of all components the filtration of the hydraulic fluid need special attention.

The sealing and gliding gaps in hydraulic components typically are in the range of 3-10 µm. That means they are in the same size range as most of the particles found in a hydraulic fluid.

The smaller the number of particles in a hydraulic fluid, the lower the wear of the hydraulic components will be. And wear is by nearly 90% the root cause for failure of hydraulic pumps and motors.

To ensure a disruption free operation of a general hydraulic system, at least a fluid quality (cleanliness level) of 20/18/15 according to ISO 4406 is required. The characteristic values indicate, how many particles in the size range >2 µm (1. value), >5µm 2. value) and >15 µm (3. value) are present in one ml of a fluid. The value 20 stands for 5.000 – 10.000 particles per ml, the 18 stands for 1.300 - 2.500 particles per ml, and the 15 for 160 – 320 particles per ml.

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Heat Dissipation / Seals

That illustrates, that a hydraulic fluid of the cleanliness level 20/18/15 still a huge number of particles is distributed in the fluid content. That also indicates, that this fluid quality only for general and low pressure applications is good enough.

When the requirements in functional safety and operational life are higher or at high pressure applications Parker recommends a cleanliness level 18/16/13 acc. ISO 4406. The fluid then is allowed to contain 1.300 – 2.500 particels >4µm, 320 – 640 particles >6µm and 40 – 80 particles >14 µm per ml.

To achieve a cleanliness level the hydraulic circuit must be equipped with a suitable filtration system. But it has to be considered that filters never perform an absolute cleaning of the fluid. A filter element with a $\beta_{10} \geq 75$ does not retain all particles larger than 10µm. Still 1/75 of all particles larger than 10µm will pass the element.

This review shows
- A reservoir filling of 100 l contains billions of contamination particles
- Even a „10µ-filter“ will let pass millions of particles >10 µm

On top of that it needs to be considered:
- across a breather and through the piston rod seal and wiper of a hydraulic cylinder particles can enter a hydraulic system
- wear on pumps, motors and valves adds more particles to the fluid
- mineral oil delivered in barrels typically has a cleanliness level of 21/19/16 according to ISO 4406 or worse.

Therefore it is very important, to pay highest attention also to the systems filtration in respect of its layout, its supervision and its maintenance.

The load to the fluid in hydraulic systems leads to its aging. Therefore the fluid needs to be checked for its perfect condition. This check should be performed at least twice a year and include as a minimum requirement the determination of neutralization number, viscosity, colour index and cleanliness level.

The operational life of the fluid depends very much on the operating pressure, the operating temperature, the circulation number (delivery of all pumps divided by the reservoir content) and the type of the fluid. General statements to the average time of usage therefore are impossible.

Heat dissipation

The temperature has an important influence on the properties of the hydraulic fluid. Viscosity, lubricity, aging and other significant features depend direct or indirectly on the temperature. That indicates, that the thermal balance of a hydraulic system needs to be considered during the layout and design. On one hand the fluid is stressed by a high temperature, on the other hand the fluid is the medium to transport the heat away from resistors, orifices and other throttling devices and friction zones. Therefore during layout it has to be made sure, that nowhere in the system a local overheating by dissipated heat can occur. That could destroy seals, lead to a failure of components due to lack of lubricity or finally lead to a destruction of the fluid itself.

A final comment to seals. A good hydraulic system should not show, that it operates with a fluid. There should be no leakage at all. In general hydraulic components are leak free. More than 90% of all problems occur at interfaces
- Ports
- Flange interfaces of valves
- Connectors

The assembly of the system is the main cause for problems in this area.

Nevertheless the system “hydraulic fluid & elastometric seal” is extremely sensitive. Temperature, chemical incompatibility and mechanical damages are the most frequent causes for a failure of this system. Please contact Parker if you have any question to this topic.

Parker does not give an explicit recommendation for a certain fluid product, fluid brand or fluid manufacturer. The permanent research and development in the field of hydraulic fluids and seal materials makes it impossible to test all possible combinations for compatibility with our components. The recommendations made here and the discussion of possible restrictions, relevant standards and other useful literature should help to select the right fluid for a hydraulic system and to design the power unit in a way that it is able to fulfill all requirements.
Special fluids for environment protection

All statements made above are in principle also valid for these fluids. Regarding the selection/definition of the required viscosity level, the cleanliness level and the lubrication and wear protection behavior all criteria discussed in the mineral oil section have to be applied accordingly.

The following special fluid features and conditions are to be considered:

**Fluids based on natural ingredients**
- Good lubrication, viscosity-temperature characteristics better than standard mineral oil.
- Density slightly higher than mineral oil, therefore check for good suction conditions!
- Pour point approx. – 30°, therefore not suitable for low temperature operation.
- Accelerated aging. First fluid change after 500 h, second change after another 1,000 h. Then all 2,000 h or annually, if less than 2,000 h annual operation.
- High affinity to water. The ingestion of water has to be avoided under all conditions. At temperature above 50°C destroys the fluid if water is present.
- Can be mixed with mineral oil (under loss of biological degradability!)
- Internal coating of reservoirs etc. to be compatible with the fluid. Check with fluid supplier.

**Fluids basing on esters (synthetical esters)**
- The same remarks as for fluids based on natural ingredients

**Fluids basing on polyglycol (not HFC/water glycol)**
- Good lubrication, viscosity-temperature characteristic better than standard mineral oil.
- Aging/durability according to actual knowledge similar to mineral oil.
- Pourpoint approx. – 40°C, be careful at low temperatures!
- Density significantly higher than at mineral oil. Therefore the max. input speeds for self priming pumps are to be reduced by 20%.
- Use fluorcarbon as seal material. Our hydraulic components are tested with mineral oil; they need to be completely made empty before installation!
- Normal paints and coatings are destroyed. Please contact fluid supplier!
- Never mix with mineral oil, solid sediments will develop and block filters, orifices etc.!

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**Note!**

Even bio-degradable fluids need to be disposed according to special disposing rules (like mineral oil). Prior to the use of these fluids we recommend to contact our specialists.

**Fluids according to DIN 51 502 (HF-Fluids)**
These fluids are fire resistant. The following classes are used:

- HFA oil in water emulsion: 95 – 98% water
- HFB water in oil emulsion: >40% water
- HFC water containing solutions: 35 – 55% water (poly-glycole)
- HFD water free fluids (mainly phosphor acid ester).

The operation of Parker hydraulic components with HFD fluids within the limits of the fluid suppliers specification (temperature range, filtration, seal material compatibility) and the viscosity limits of our components is possible without restrictions.

The operation with HFC involves certain restrictions regarding pressure limitation and bearing life reduction in rotating units. Please contact our specialists. Parker does not give a general release for the operation with HFA and HFB fluids. In certain cases a special approval can be given upon request.

If you are not sure, whether our products can be used with a special fluid or not, please call us. Our specialists are glad to answer your questions and to give you any necessary support.