

## Premium quality hydraulic oils

MILAN KAMBIČ

**Abstract** The base of the final product is the base oil. The final product is ready for use and is a mixture of base oil (or several base oils) and additives. Additives improve the properties of the base oil. Base oils can be mineral or synthetic based. Base oils or base stocks are created from separating and cleaning up crude oil. They are one of several liquid components that are created from crude oil. The crude oil refining process will be briefly described. The American Petroleum Institute implemented a system for describing various base oil types. The result was the development and introduction of base oils group numbers. The API numbers of various base oil groups and the main differences between them will be explained. At the end, premium quality hydraulic oil and its main characteristics will be presented.

**Keywords:** • base oils • refining • API group numbers • hydraulic oil • additives •

## 1 Introduction

The hydraulic fluid is a very important component that is often casually considered. Most often, satisfying the requirements of only the pump seems to be the primary consideration for fluid selection [1]. Although the costs of hydraulic pump failures are generally one of the costlier occurrences within hydraulic systems, erratic operation of valves and actuators due to inadequate oil performance characteristics such as oil degradation (oxidation) that causes deposits to form in critical clearance areas, often leads to costly production losses [1], [2]. With the close clearances, different metallurgies, various elastomers, and high pressures and temperatures, service life and performance of all the system components depend on proper selection and maintenance of the hydraulic fluids.

Hydraulic fluids perform many functions in addition to transmitting pressure and energy. These include minimizing friction and wear, sealing close-clearance parts from leakage, removing heat, minimizing system deposits, flushing away wear particles and contamination, and protecting surfaces from rust and corrosion. The important characteristics of a hydraulic fluid vary by the components used and the severity of service [2]. A number of the physical characteristics and performance qualities of hydraulic fluids commonly required by most hydraulic systems are:

- viscosity,
- viscosity index (VI),
- wear protection capability,
- oxidation stability,
- antifoam and air separation characteristics,
- demulsibility (water-separating characteristics),
- rust protection,
- compatibility.

Oil qualities required by hydraulic systems depend on appliance. From the very beginning of the use of hydraulic fluids, man strives to improve their properties. As a result, in the good two centuries of their use, the number of different fluids used in hydraulic devices today has increased considerably. Each of them has advantages in a particular area of application. For example, water is non-combustible, mineral oil is the most universally useful, biodegradable oils are less

harmful to the environment, hydraulic oils for use in the food industry can come into contact with food etc. However, no liquid is so universal that it can meet sometimes very different or even contradictory requirements in individual applications. Development engineers are therefore still investing a tremendous amount of effort, time and resources in finding a hydraulic fluid that would be close to the ideal hydraulic fluid. Among other things, it should be non-flammable, non-toxic, have excellent lubricating properties, temperature-independent physicochemical properties [3], [4], [5].

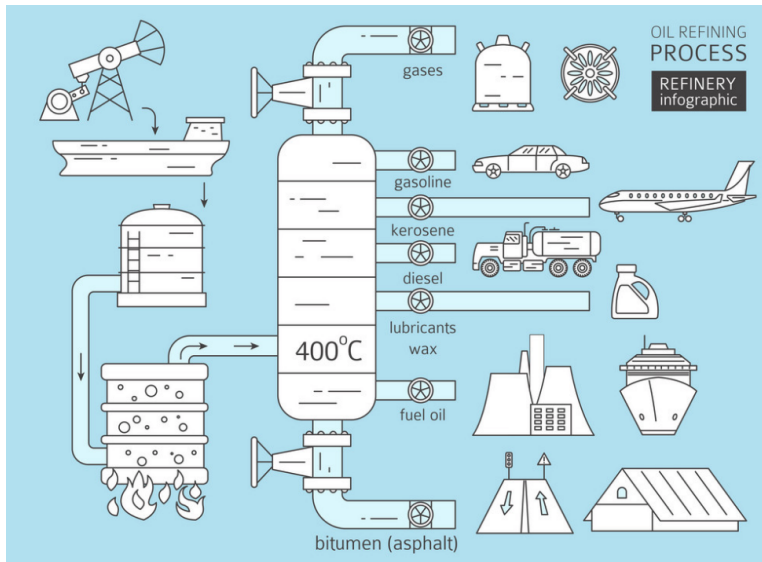
The article will present a premium quality hydraulic fluid based on mineral oil. Therefore, the process of production of mineral base oils will be briefly described below.

## **2 Mineral base oils**

The base of the final product is the base oil. The final product is ready for use and is a mixture of base oil (or several base oils) and additives. Additives improve the properties of the base oil. Base oils can be mineral or synthetic based [6].

### **2.1 Production of mineral base oils**

The basic function of a refinery is to separate the crude oil into its useful components and remove the components of unwanted materials. Base oils or base stocks, as they are sometimes called, are created from separating and cleaning up crude oil. They are one of several liquid components that are created from crude oil. Gasoline is the lightest or smallest hydrocarbon component, followed by kerosene, or jet fuel, diesel fuel, base oils, waxes and asphalt or bitumen, which is the heaviest, thickest material. Base oils are prepared from crude oils through the use of the following series of processes which, to some degree, must be applied to all crude oils for refining processes. Base oils are typically created in four different viscosity grades within the refinery distillation process. This allows for the creation of the various ISO and API viscosity grades [6], [7].



**Figure 1: Schematic representation of the crude oil distillation process [8].**

Those processes are:

- Atmospheric distillation-is used initially to separate fuel, such as gasoline and diesel, from the remainder of the crude petroleum. Distillation is a separation process. The products of distillation are referred as distillates.
- Vacuum distillation-is performed to distill and therefore separate some heavier fractions that would not distill at atmospheric pressure without damaging them. It is used to obtain the initial base oil viscosity and flash point characteristics. This process provides the four various viscosity fractions (or distillates) from which the finished products are made.
- Refining-is performed to remove unwanted chemical structures (rings, etc.) from the base oil to reduce the tendency of the base oil to age in service and also to improve the viscosity/temperature characteristics.

Three basic refining processes are used by oil companies:

- a) Sulphuric acid/clay refining (old, out-dated technology);
- b) Solvent extraction;
- c) Catalytic hydrogenation or hydrotreating<sup>1</sup>.

<sup>1</sup> Hydrofinishing, hydrogenation or “hydrotreating”, and high pressure hydrogenation or hydrocracking are three forms of increasing severity of using hydrogen gas to purify or clean crude oil to create base oils.

- De asphalt-ing-is a step in the process to removes the heavy asphalt residue from the useful distillate fractions.
- De-waxing-is a step that is performed to reduce wax content of the base oil in order to improve the low temperature properties of the oil.
- Blending-is the final process in producing a finished lubrication oil. It involves the blending of different base oils to obtain the necessary viscosity, as well as the addition of specified additives to ensure that the finished oil has the right properties to provide to provide the intended lubricating ability.

## 2.2 API Group numbers

Almost every lubricant used in plants today started off as just a base oil. The American Petroleum Institute (API) has categorized base oils into five categories (API 1509, Appendix E). The first three groups are refined from petroleum crude oil.

Group IV base oils are full synthetic (polyalphaolefin) oils. Group V is for all other base oils not included in Groups I through IV. Before all the additives are added to the mixture, lubricating oils begin as one or more of these five API groups [9].

Group I base oils are the traditional older base oils created by a solvent-refining technology used to remove the weaker chemical structures or bad actors (ring structures, structures with double bonds) from the crude oil. Solvent refining was the primary technology used refineries built between 1940 and 1980. Group I base oils typically range from amber to golden brown in colour due to the sulphur, nitrogen and ring structures remaining in the oil. They typically have viscosity index (VI) from 90 to 105. Group I base oils are the most common type used for industrial oils, although increasingly more Group II base oils are being used [6].

The Table 1 indicates general trends in certain properties and the chemical makeup of some of tGroup I, II, II and IV base oils.

**Table 1: General base oil properties [6]**

	<b>Naphthenic (Severely hydrotreated)</b>	<b>Group I</b>	<b>Group II</b>	<b>Group III</b>	<b>Group IV</b>
<b>Viscosity index</b>	30-60	95	105	130	130
<b>Pour point (%)</b>	-45	-15	-15	-15	<-60
<b>Volatility (%)</b>	/	25	15	5-10	10
<b>Aniline point (°C)</b>	75	100	115	130	130
<b>% Saturates (Paraffins)</b>	65	80	99	99	100
<b>% Polars &amp; Aromatics</b>	35	20	0,5	0,2	0
<b>Nitrogen (ppm)</b>	/	Up to 60	<5	<1	0
<b>Sulphur (ppm)</b>	0,05	Up to 7.000	10	<5	0

Group II base oils are created by using a hydrotreating process to replace the traditional solvent-refining process. Hydrogen gas is used to remove undesirable components from crude oil. This results in a clear and colourless base oil with very low sulphur, nitrogen or ring structures. The VI is typically above 100. In recent years, the price has become very similar to Group I base oils. Group II base oils are still considered to be mineral oils. They are commonly used in automotive engine oil formulations. Group II "Plus" is a term used for Group II base oils that have a slightly higher VI of approximately 115, although this may not be an officially recognized term by the API.

Group III base oils are again created by using a hydrogen gas process to clean up the crude oil, but this time the process is more severe and is operated at higher temperatures and pressures than used for Group II base oils. The resulting base oil is clear and colour less but also has a VI above 120. In addition, it is more

resistant to oxidation than Group I oils. The cost of Group III base oils is higher than Group I and II. Group III base oils are considered mineral oils by many technical people because they are derived directly from refining of crude oil. However, they are considered as synthetic base oils by other people for marketing purposes due to belief that the harsher hydrogen process has created new chemical oil structures that were not present before the process. It has synthesized (created) these new hydrocarbon structures.

Group IV base oils are polyalphaolefin (PAO) synthetic base oils that have existed for more than 50 years. They are pure chemicals created in a chemical plant as opposed to being created by distillation and refining of crude oil (as the previous groups were). PAOs fall into the category of synthetic hydrocarbons (SHCs). They have a VI of greater than 120 and are significantly more expensive than group III base oils due to the high degree of processing needed to manufacture them.

Group V base oils comprise all base oils not included in Groups I, II, III and IV. Therefore, naphthenic base oils, various synthetic esters, polyalkylene glycols (PAGs), phosphate esters and others fall into this group.

### **3 Development of premium quality hydraulic oil Hydrolubric HC VG 46**

The motive for the development of premium hydraulic oil is the fact that in recent years the share of hydraulic oils based on base oils of groups II and III has been increasing.

Among other things, we observed a trend in the use of such oils in plastic injection moulding machines. Hydrolubric VG 46 oil (in some cases also Hydrolubric VG 68) has been used successfully for this purpose for a long time. Hydrolubric VG 46 exceeds the oil requirements of one of the well-known manufacturers of plastic injection moulding machines Krauss Maffei. Nevertheless, some lubricant providers have been offering even higher quality oils for use on these machines for the past two or three years. Some users have also chosen to use hydraulic oils based on group II or group III base oils, or have started testing such oils in their machines. This was the main reason why we decided to develop the premium quality hydraulic oil Hydrolubric HC VG 46,

which significantly exceeds the properties of Hydrolubric VG 46 oil in terms of some properties, such as oxidative stability.

HYDROLUBRIC HC VG 46 hydraulic oil consists of specially selected hydrocracked base oils, anti-corrosion, anti-aging, EP and AW additives, viscosity improvers and anti-foaming additives. It has excellent thermal and oxidative stability, filterability (even in the presence of a small amount of water), excellent hydrolytic stability, good air release ability and is not prone to foaming.

Some physical and chemical properties of Hydrolubric HC VG 46 are shown in Table 2.

**Table 2: Physical and chemical properties of Hydrolubric HC VG 46**

	<b>Method</b>	<b>Unit</b>	<b>Limit value</b>	<b>Measured value</b>
<b>Appearance</b>	visual	/	Clear liquid	Clear liquid
<b>Colour</b>	ASTM D1500		<4	L 0.5
<b>Flash point (COC)</b>	ASTM D92	°C	>185	>240
<b>Density at 20 °C</b>	ISO 12185	kg/m <sup>3</sup>	850.0-890.0	854.5
<b>Pour point</b>	ASTM D97	°C	<-15	<-33
<b>Viscosity at 40 °C</b>	ASTM D445	mm <sup>2</sup> /s	41.4-50.6	46.21
<b>Viscosity at 100 °C</b>	ASTM D445	mm <sup>2</sup> /s	>6.100	7.125
<b>Viscosity index</b>	ASTM D2270	/	>110	113
<b>Total acid number</b>	ASTM D664	mgKOH/g	0.40-0.60	0.41
<b>Copper corrosion</b>	ASTM D130			1b
<b>Oxidation stability, RapidOxy Grease 2</b>	ASTM D8206	min		1067
<b>Deemulsivity 40/0/40 (O/E/W)</b>		min	30	<15
<b>Foaming test</b>	ASTM D892	ml/ml	150/0	0/0
			75/0	0/0
			150/0	0/0



Oxidative stability of Hydrolubric HC VG 46 was measured in comparison with some other Olma mineral-based hydraulic oils ISO VG 46. The RapidOxy 100 tester shown in Figure 2 was used. The results are shown in Table 3.



Figure 2: Oxidation Stability Tester: RapidOxy 100.

Table 3: Comparison of oxidation stability of some Olma hydraulic oils.

Product	Method	Unit	Measured value
<b>Hydroloubric HC VG 46</b>	ASTM D8206	min	1067
<b>Hydrolubric VG 46</b>	ASTM D8206	min	664
<b>Hydrolubric HD 46</b>	ASTM D8206	min	570
<b>Hydrolubric HLP 46</b>	ASTM D8206	min	529
<b>Hydrolubric VGS 46</b>	ASTM D8206	min	672
<b>Hydrolubric HVLP 46</b>	ASTM D8206	min	787
<b>Hydrolubric VG 46 D</b>	ASTM D8206	min	536

Hydrolubric HC VG 46 meets the following specifications:

- DIN 51524/3 HVLP;
- ISO 6743/4 HV;
- ISO 11158 HV;
- Denison HF-2, HF-0
- Vickers I-286-S, M-2950-S
- Cincinnati Milacron P-68, P-69, P-70;
- AFNOR NFE 48-690 (dry);
- AFNOR NFE 48-691 (wet);
- AFNOR NFE 48-603.

After conducting laboratory tests in the laboratory of the company Olma, which confirmed our expectations, we started practical testing in some plastic injection moulding machines Krauss Maffei in three companies. We performed the first analyses of oil samples from these machines. However, it will be necessary to wait a longer time for the conclusions, as we can expect that the service life of the oil under normal conditions of use will be several years.

#### **4 Conclusion**

Due to the increase in the share of hydraulic oils based on higher quality base oils, which we have seen on the market in recent years, we decided to develop a premium hydraulic oil Hydrolubric HC VG 46.

Laboratory measurements have confirmed the expectation that this oil will exceed the properties of conventional hydraulic oils. The oxidation stability of this oil is significantly higher than that of other conventional hydraulic oils.

We started practical testing in some plastic injection moulding machines Krauss Maffei in three companies. However, it will be necessary to wait a longer time for the conclusions, as we can expect that the service life of the oil under normal conditions of use will be several years.

## References

- [1] Kambič, M., Lovrec, D. Lovrec (2017). Problems of testing new hydraulic fluids. *Fluid power 2017*, Maribor
- [2] Pirro, -M. D., Wessol, A. A. (2001). Lubrication fundamentals, 2nd ed., New York, Basel: Marcel Dekker, Inc
- [3] Kambič, M., Lovrec, D. (2011). Hidravlične tekočine prihodnosti. *Fluidna tehnika 2011*, Maribor
- [4] Kambič, M., Kalb, R. (2013). Comparison of ionic liquids with conventional mineral oils. *Fluid Power 2013*, Maribor
- [5] Kambič, M., Kalb, R., Lovrec, D. Lovrec. (2015). Lubrication properties of ionic liquids suitable for use within hydraulic systems. *Fluid Power 2021*, Maribor
- [6] Scott, R., Fitch, J., Leugner, L. (2012) The practical handbook of machinery lubrication. Tulsa, Oklahoma: Noria Corporation
- [7] Kambič M., Mineralna bazna olja. *IRT3000*, Izv. 16, št. 114, 2021.
- [8] Noria corporation. Oil refinery process infographic crude oil vector image. [Online]. Available: <https://www.vectorstock.com/royalty-free-vector/oil-refinery-process-infographic-crude-oil-vector-35612726>. [Accessed 14. 5. 2021].
- [9] Base oil groups explained. *Machinery lubrication*, no. 10, September-October 2012.

