

# Demystifying hydraulic fluids

## Understanding ISO/DIN/EN classifications and mineral oil-based hydraulic fluids

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*When you think about the smooth operation of heavy machinery, elevators gliding seamlessly between floors, or the effortless motion of your car's power steering system, hydraulic fluids play a pivotal role behind the scenes. These unassuming fluids are the lifeline of countless systems integral to our daily lives. But what makes hydraulic fluids so special? Dennis Poon, Technical Support & Development Manager at SIP Specialty Oils and Fluids, demystify these essential lubricants by taking an in-depth look at the hydraulic systems, fluids and different classifications that govern them.*

### The Foundation: Pascal's Law

To truly appreciate hydraulic fluids, we must first travel back to the 17th century. Blaise Pascal, the French polymath, is often revered for his pioneering work in mathematics, physics, and philosophy. Not only did he invent the mechanical calculator, a precursor to the modern computer, but his scientific contributions continue to influence various industries to this day.<sup>1</sup>

In 1653, Pascal formulated what we now refer to as Pascal's Law. This fundamental concept states that when pressure is applied at any point in a confined fluid, it is transmitted equally in all directions throughout the fluid. Put simply, if you apply pressure to a small area, the resulting force will be proportionally increased across the fluid. This principle forms the foundation of hydraulic systems, which rely on the transmission of force through fluids to achieve remarkable feats of mechanical advantage.

### Types of hydraulic systems/pumps

Fast forward to the modern era, at their core, hydraulic systems utilise fluid to generate force and motion. This power is harnessed by using incompressible fluids, typically oils, which allow heavy loads to be moved with precision and ease. The principles governing these systems can be

broadly categorised into two types: Hydrokinetic and hydrostatic systems (Figure 1).

Hydrokinetic systems, also known as dynamic systems, use the dynamic movement of fluids to transmit power. These are prevalent in applications where there is a need for variable speed and smooth transitions. The primary type of machine used in hydrokinetic systems is the centrifugal pump. These pumps use the rotational energy from an impeller to increase the fluid's velocity and convert that kinetic energy into pressure. They are ideal for pumping large volumes of fluid at low pressures and are commonly found in water treatment plants, HVAC systems, and irrigation applications.

Hydrostatic systems, or positive displacement systems, work by trapping a fixed amount of fluid and forcing (displacing) it into a hydraulic system. These systems are more suited for applications requiring high pressures and precision control, supported by three pumping methods:

**Piston pumps** – these pumps have pistons that move within a cylinder, creating a precise flow of fluid. They can manage very high pressures and are used in heavy machinery, such as construction equipment and industrial presses.

<sup>1</sup> Prof. S. Chapman, F.R.S., NATURE, Oct. 31, 1942, Vol. 150, pg. 508-509

**Gear pumps** – Gear pumps use the meshing of gears to pump fluid by displacement. They are sturdy and simple, ideal for hydraulic systems in agricultural machinery and chemical processing.

**Vane pumps** – Vane pumps utilise retractable vanes that slide within a rotor to move the fluid. These are quieter and offer smooth flow, making them suitable for automotive power steering and mobile machinery.

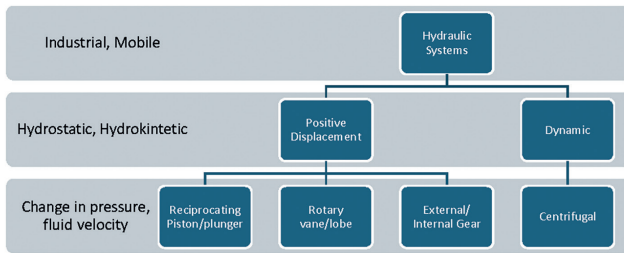


Figure 1: Hydraulic Systems/pumps

### Understanding hydraulic fluid classifications

Hydraulic fluids are classified according to various ISO, DIN, and EN standards, which assist in distinguishing different types of hydraulic fluids.

ISO (International Organization for Standardization) establishes global standards, whereas DIN (Deutsches Institut für Normung) is the German Institute for Standardisation, with its standards commonly used in Germany and often forming the basis for EN standards. EN (European Norm) standards are harmonised standards adopted by the European Union (EU) member states to ensure consistency and facilitate trade within the EU.

The ISO 6743-4 classification system categorises hydraulic fluids into three main classes: Mineral Oils (ISO 11158 – HH, HL, HM, HV and HG), Fire-Resistant (ISO 12922 – HFAE, HFAS, HFB, HFC, HFDR and HFDU), and Environmentally Acceptable (ISO 15380 – HETG, HEPG, HEES and HEPR) fluids, as depicted in Figure 2.<sup>2</sup>

DIN 51524, which sits within the mineral oils category, can be subdivided into DIN 51524-1 (HL), DIN 51524-2 (HLP, HLPD), and DIN 51524-3 (HVL, HVL, HVL, HVL). Hydraulic fluids such as HL, HLP, HLPD, HVL, and HVL each offer distinct advantages. For instance, HL fluids ensure basic lubrication, oxidation

and corrosion protection, while HLP fluids enhance anti-wear properties. HVL and HVL fluids excel in cold temperature operability and running efficiency, with HVL also offering superior detergency to keep deposits suspended.

EN 16807 specifies the term ‘bio-lubricant’ and sets minimum requirements for all types of bio-lubricants and bio-based lubricants. Specifically, environmentally acceptable hydraulic fluids (as per ISO 15380) must meet EN 16807 standards regarding biodegradability, toxicity, and, in the case of HETG and HERS fluids, a minimum carbon content from biological sources.

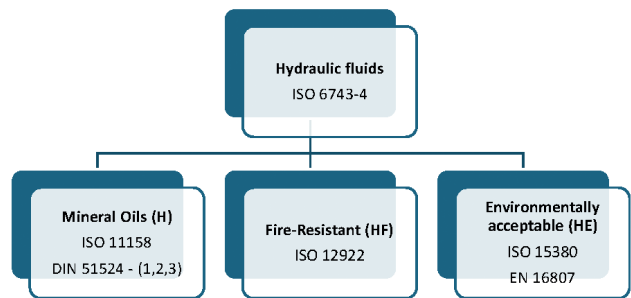


Figure 2: Relevant Hydraulic fluids classification

### Factors to consider when selecting a hydraulic fluid

Selecting the right fluids for your hydraulic systems is crucial for optimal performance, efficiency, and equipment longevity. By understanding the type of pump, viscosity grade, and base oil requirements, you can ensure a well-matched pairing that will keep your equipment running smoothly.

There are several key factors to consider...

**Bulk modulus:** Bulk modulus defines how much an oil will compress or deform when subjected to an external force. It is crucial for its effectiveness in power transmission as it affects the fluid’s ability to transfer force efficiently and smoothly. It has been shown that an improvement of 0.6GPa can improve the speed and stability of the system by 20% respectively.<sup>3</sup>

Higher viscosity fluid tends to equate to higher bulk modulus. However, as the industry shifts towards energy conservation, it is essential to strike a balance between viscosity modifications and maintaining

<sup>2</sup> ISO 6743-4 does not include automotive brake fluids or aircraft hydraulic fluids

<sup>3</sup> T. Tsubouchi, H. Kamimura and J. Shinoda, “Development of oily high bulk modulus fluid”, Proceedings of the 7th JFPS International Symposium on Fluid Power, Toyama, 2, 2008, 329-334

critical properties like bulk modulus to ensure the reliable functionality of hydraulic systems.

**Air entrainment:** Characterised by prolonged air release times and foam formation, are a significant issue impacting the performance of industrial oils. This phenomenon can lead to reduced operational efficiency and increased noise levels in pumps, compressors, and gear systems.<sup>4</sup> As the foam does not have the characteristics of hydraulic fluid, it cannot form a continuous oil film on the surface of the components, resulting in excessive wear of the components due to lack of lubrication. In order to avoid this phenomenon, hydraulic fluid must have good air release and foam resistance. Highly refined mineral oils and additives can be used to mitigate these issues.

**Viscosity and viscosity index:** Hydraulic fluids are designed to operate within specific temperature ranges. Adequate viscosity ensures effective lubrication and sealing, preventing leaks in pumps, valves, motors, and other components. Conversely, excessive viscosity can impede fluid flow, reducing the system's mechanical efficiency. Understanding the viscosity index is crucial as it helps assess the temperature stability of hydraulic oil, ensuring it delivers optimal performance across a wide range of environmental conditions.

**Thermal and oxidative stability:** In the realm of hydraulic fluid performance, thermal and oxidative stability are paramount. Modern fast-acting stop-start systems demand hydraulic components that are impeccably clean and hydraulic fluids free from particulate contamination. Such systems subject hydraulic fluids to intense temperature fluctuations and oxidative stress, which can degrade fluid quality and performance. To combat these challenges, highly refined oils with suitable additives are essential. These advanced formulations enhance the fluid's resistance to thermal breakdown and oxidative degradation.

## Commercially available mineral oil-based components and viscosity grades -

### Physical properties

A market survey revealed that ISO VG 32, 46, and 68

viscosities are the most commonly available mineral oil-based hydraulic lubricants. Within this range, the median viscosity index (VI) ranges from 106 to 111, with 35% of ISO VG 32 and 46 grades exhibiting a viscosity index greater than 140 which classified as DIN 51624-3 HVLP lubricants. The median pour points of all three grades range from -27°C to -33°C, as shown in Table 1, and they exhibit good cold flow qualities. It's worth noting that certain arctic grade lubricant products exhibit a pour point below -57°C.

	PP range, °C	Median PP, °C	VI range	Median VI	% of product VI > 140
ISO VG 32	-24 to -54	-33	96-200	111	35
ISO VG 46	-15 to -48	-33	96-192	106	35
ISO VG 68	-15 to -45	-27	95-162	107	27

**Table 1:** Key ISO grades physical properties

### Chemical identities

Having explored their physical properties, let's now delve into the intricate chemical aspects of these oils. Our analysis delineates a number of blending components that can be broadly classified as paraffinic, naphthenic, and white oils, as illustrated in Figure 3.

Within the paraffinic category, further sub-categorisation is possible into hydrotreated and solvent/catalytic dewaxed oils. Among the hydrotreated components, one typically encounters distillates, hydrotreated light and heavy paraffinic oils, hydrotreated neutral oil-based oils, solvent dewaxed heavy paraffinic, and catalytic dewaxed light oils. Solvent dewaxing is often used in the production of Group I base oils. Hydrotreated paraffinic oils, refined through hydrotreating and catalytic dewaxing processes, can fall under Group II, or Group III oils. Both groups are known for their enhanced purity and stability.

In the naphthenic category, hydrotreated light and heavy naphthenic oils are often used as blending components in conjunction with hydrotreated paraffinic oils. These naphthenic oils exhibit excellent solubilising properties for polar additives and oxygenates that can form in the oil during hydraulic system operations. Additionally, their remarkable low-temperature characteristics and compatibility with seals make them ideal components for hydraulic fluids blending.

<sup>4</sup> Biswajit Basu, Subhash Chand, Jayaprakash, K.C., Sivastava, S.P., and Goel, P.K., 'Air-entrainment phenomenon in mineral lubricating oils', ASLE Trans., 28, 313 (1985).

White oils, renowned for their purity and stability, play a crucial role in both conventional industrial applications and the formulation of food-grade hydraulic fluids. Their inert properties and adherence to stringent food safety standards establish them as essential processing aids within the food industry, often suitable for direct/indirect food contact. White oil-based hydraulic fluids exhibit exceptional resistance to oxidative degradation, even at high temperatures and in wet processing environments, thus extending equipment life and minimising operational downtime.

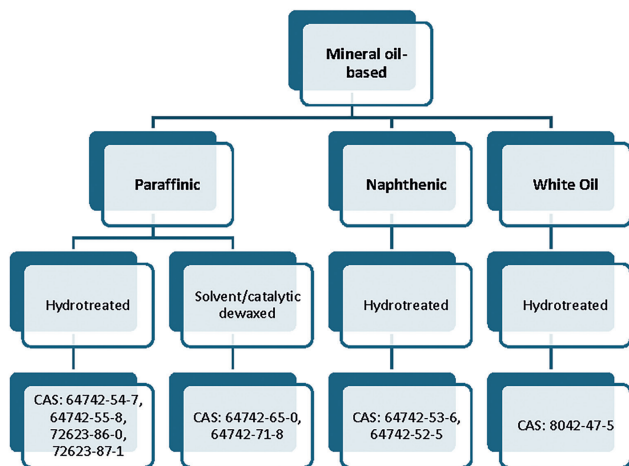


Figure 3: Typical mineral oil-based components for hydraulic base oils

### Embracing the future

Despite ongoing advancements, mineral oil-based hydraulic fluids continue to dominate the market due to their well-balanced performance characteristics and cost effectiveness. The role of additive technology has been pivotal in enhancing these conventional fluids, contributing to improved performance, protection against wear, and extended oil life.

The growing need for sustainable options is driving innovation towards renewable and biodegradable components.<sup>5</sup> Such alternatives are formulated to meet stringent environmental regulations while minimising the ecological impact, especially in sensitive applications where oil leaks or spills might occur. Embracing these sustainable solutions represents a significant shift towards responsible resource management and environmental stewardship, aligning with global sustainability goals.



<sup>5</sup> <https://bioba.se/wp-content/uploads/2024/05/BIO-BASE-4-10-15-22-TDS-EN-REV-9-1.pdf>