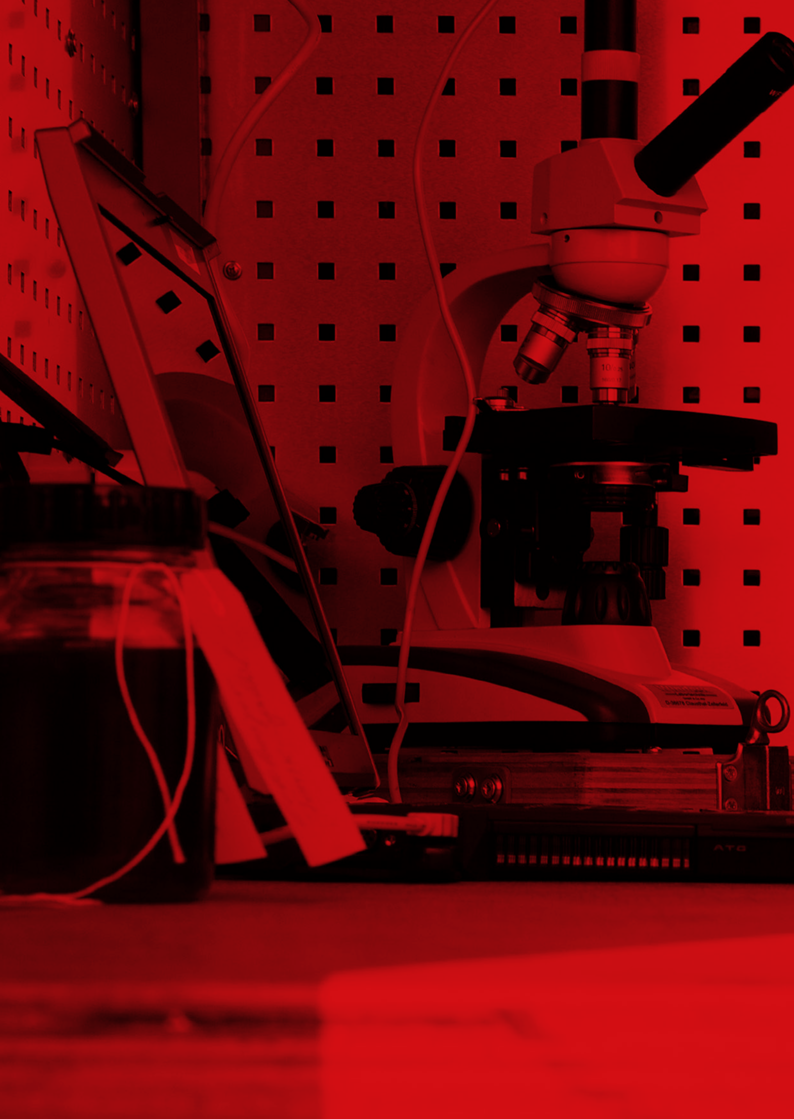
HANSA-FLEX

A concise guide to fluid management

Recognising oil-related machine problems in good time and taking precautions to prevent them



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"Hydraulic oil contamination is the main cause of over 80 % of hydraulic system failures."

Source: Lange, Klaus, Flüssiges Gold, Hüthig-Verlag Heidelberg 2001, page 63.

Hydraulic oil – the undervalued part of the machine

Hydraulic fluid is much more than any old operating medium. As an important part of the machine, it is crucially important in the design, operation and maintenance of hydraulic systems.

Modern hydraulic systems are noted for shortened cycle times, higher temperatures and pressures, reduced manufacturing tolerances between components and more compact designs, with smaller tanks and higher speeds of revolution. The requirements for the quality and cleanliness of the hydraulic oils used have therefore continuously risen over recent years.

Contaminated hydraulic oils continue to be responsible for more than three quarters of all failures of hydraulic systems today.

Users and manufacturers of stationary and mobile hydraulic systems must be aware of the importance of hydraulic fluids. Their proper selection, care and monitoring is an essential component in the efficient operation and value retention of systems and components.

Warning signs of oil-related machine problems

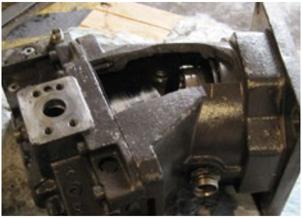
Contamination of hydraulic fluids can cause serious damage to components in hydraulic systems. Early detection of irregularities in the operation of machines can save a lot of time and money. A machine breakdown is often the first sign of contaminated hydraulic oil.

You should look out for the following warning signs:

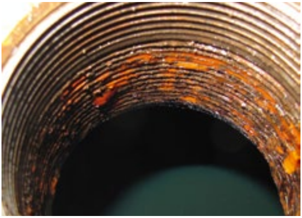
- Unusual wear of seals and hydraulic hose lines
- Metal wear residues
- Cylinder leaks, scoring
- Pump failures, reduced volumetric flow
- System pressure reductions
- Frequent need to replace parts
- Short filter replacement intervals
- Variations in speed due to scored valve pistons
- Internal and external leaks on components

Examples of oil-related component damage

Defective axial piston pump due to oil contamination

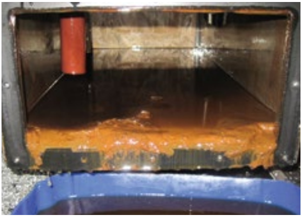


Defective hydraulic motor due to air in the system

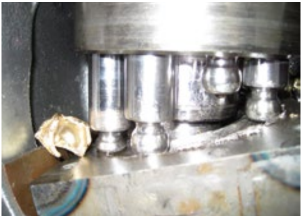


Corrosion of threaded connections on a hydraulic tank due to high atmospheric moisture content

Contaminated system filter due to eroded hose inner layers



Oil aging products in the tank



Axial pump damage due to cavitation

Damaging effects on hydraulic oils

Solids

Contamination of hydraulic oil by solid particles

Air

Entrained air in hydraulic oil

Mixing

Mixing of different hydraulic oils

Water

Water contamination
in hydraulic oil

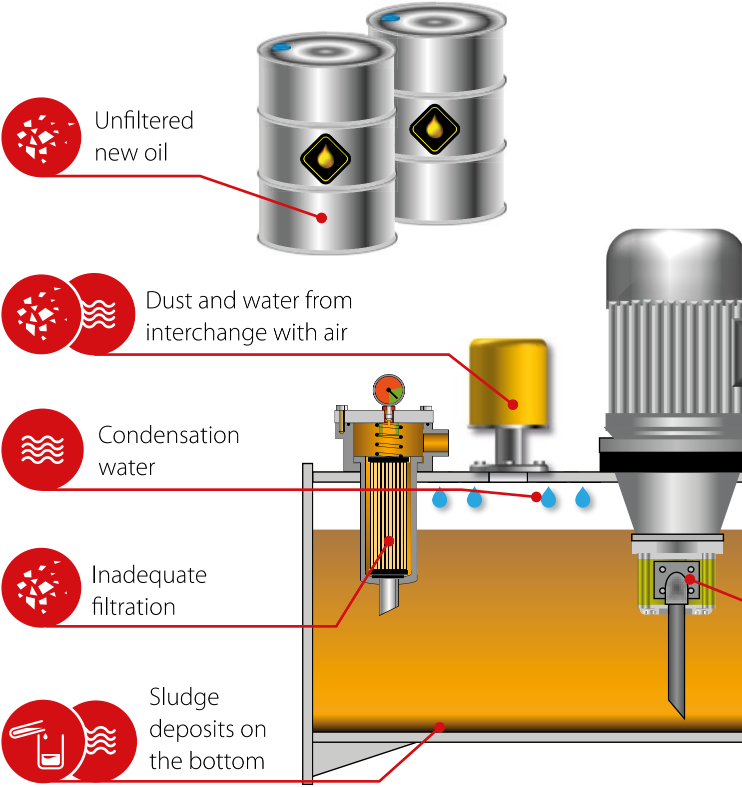
Temperature

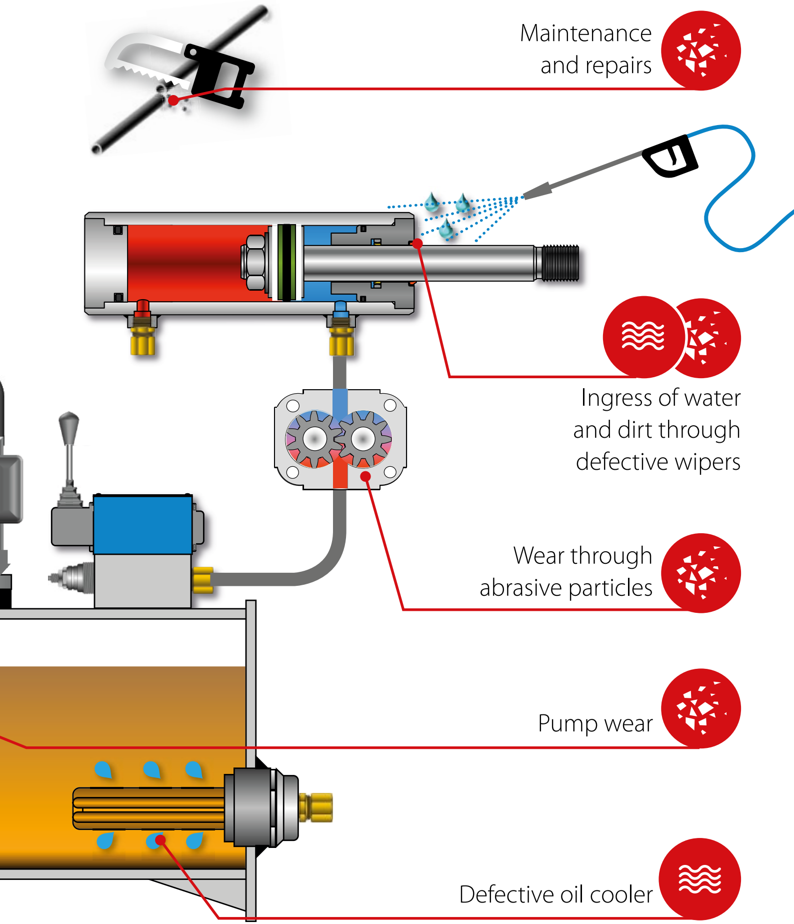
Too high operating or
ambient temperatures

Shear

Overloading of the hydraulic
oil due to too high pressures
and temperatures

Ingress and occurrence of fluid contaminants in hydraulic systems




Maintenance
and repairs
Ingress of water
and dirt through
defective wipers
Wear through
abrasive particles
Pump wear
Defective oil cooler

Contamination by solids

Contamination of the hydraulic oil by solids such as metal particles, seal particles and dust is one of the commonest causes of damage.

External causes

- Filling with unfiltered new oil (see page 26)
- Poor filter design in the tank vent port
- Defective wipers and seals on the hydraulic cylinders and piston rods
- Ingress during repairs and installation work on the hydraulic system
- Ingress during replacement of hydraulic hoses, particular-ly when operating tools are interchanged

- Incorrectly connected removable partial flow filter systems
- Leaking oil coolers or defective tank seals
- Ingress of contaminants from the environment

Internal causes

- Erosion to the control surfaces of the valve spool by dirt particles
- New particulate created due to surface fatigue caused by high fluctuations in pressure and stresses
- Corrosion due to water in the oil
- Cavitation wear caused by water or air in the oil

Consequences

- Greater wear of components (valves, pumps, cylinders, motors, seals and hydraulic hose lines)
- Sticking valves
- Increased wear of filter elements
- Blockage of ports in valves
- Leaks at pumps, valves, motors, cylinders
- Reduced efficiency

Recommendations

- Install suitable filter systems (pressure, return flow, suction, partial flow and tank vent port filters)
- Use high-quality filter elements
- Carry out regular servicing
- Flush the system before bringing into use
- Use only filtered oil for the system
- Monitor oil condition regularly using oil analysis
- Use particle counters on site

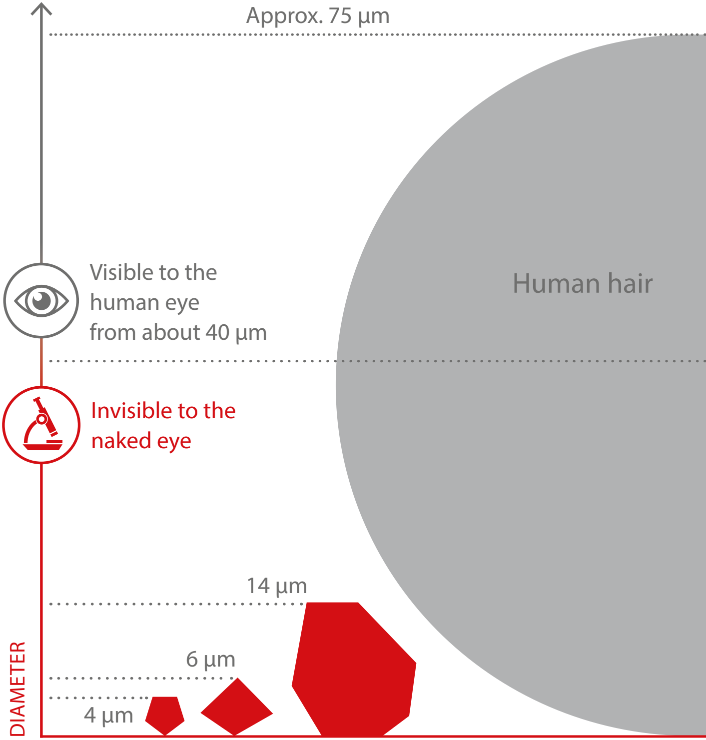
The unit of measurement for the size of solid particles is the micrometre. A micrometre (µm) is a millionth of a metre. The smallest object the human eye can see measures about 40 µm.

Particles are classified into the following size classes according to ISO 4406:1999

≥ 4 µm / ≥ 6 µm / ≥ 14 µm

and cannot therefore be seen with the naked eye. Hence, hydraulic oil may look completely clean, but may be heavily contaminated with solid particles.

Fine solid particles are invisible to the naked eye



Contamination by water

Contamination of hydraulic oil by water entering from outside the system or from condensation causes corrosion and various other types of damage.

Causes

- Cleaning the plant or equipment with steam jets
- Condensation formed by the ingress of fresh air
- Defective oil cooler (leaks in the cooling system)
- Ingress of spray water
- Contaminated new oil
- Defective cylinder seals

Consequences

- Corrosion
- Cavitation
- Oxidation
- Changes in viscosity
- Sludge formation
- Foaming
- Degradation of air release properties
- Increased wear on components (pumps, valves, cylinders)
- Acid formation
- Filter blockages
- Swelling of elastomers and hydraulic hose lines
- Premature aging of the oil
- Reduced efficiency
- Increased friction with associated greater wear

Recommendations

- Avoid ingress of external water
- Use fresh air moisture absorbers
- Use vacuum dewatering systems
- Monitor oil condition regularly using oil analyses and sensors

Air

Too much entrained air in hydraulic oil can lead to severe component damage.

Causes

- Insufficient volume of oil in the tank
- Leaks in the suction lines to the pump
- Leaks in the suction filter
- Poor venting during commissioning
- Inadequate venting of the cylinder
- Oil tank too small
- Inadequate air release properties of the oil
- Installation errors

Consequences

- Cavitation
- Oxidation
- Micro-diesel effect
- Oil foaming
- Increased component wear in pumps, valves, cylinders, motors and hydraulic hose lines
- Destruction of seals
- Poor control and regulation of the plant or equipment
- Reduced efficiency
- Premature oil aging, shorter oil change intervals

Recommendations

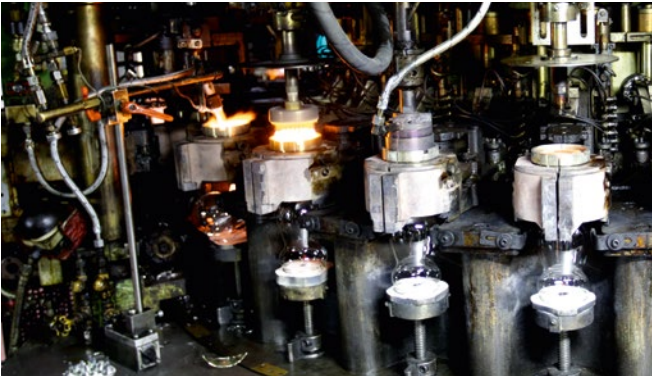
- Check the oil volume in the tank regularly
- Always vent the system properly when bringing into use and after repairs, pre-fill components with oil if necessary
- Calculate the correct size and shape of the tank during design
- Monitor the air release properties of the oil
- Use a high-quality oil suitable for the purpose
- Monitor oil condition regularly using oil analyses to check on the air release properties

Temperature

Too high operating or ambient temperatures reduce the performance of hydraulic oil.

Causes

- Too high ambient temperatures
- Unreliable throttle settings
- Tanks too small
- Hydraulic pump volumetric flow too great
- Cross sections of hydraulic pipes and hose lines too small
- Incorrect settings of the valves and pumps
- Defective or dirty oil cooler



Consequences

- Shorter oil change intervals
- Failure of additives
- Acid formation in the oil
- Failure of elastomers and hydraulic hose lines
- Sludge formation due to additive failure
- Lacquer formation
- Changes in viscosity
- Increased oxidation of the oil
- Increased wear on components
- Reduced efficiency

Recommendations

- Check the oil volume in the tank regularly
- Calculate the correct size and shape of the tank during design
- Calculate pressures and volumetric flows correctly, if necessary recalculate
- Use a high-quality oil suitable for the purpose
- Fit an oil cooler
- Monitor temperatures regularly
- Monitor oil condition regularly using oil analyses and sensors

Mixing

The mixing of different hydraulic fluids often leads to a dramatic worsening of their physical properties.

Causes

The mixing of different, not absolutely identical hydraulic fluids by users frequently occurs when topping off, interchanging attachments or during oil changes. This includes all types of incorrect mixing, for example:

- Hydraulic oils with different classifications (HLP/HLPD/HVLP)
- Zinc-free and zinc-containing hydraulic oils
- Hydraulic oils and motor oils
- Oils with detergent and oils without detergent properties
- Oils of the same classification, same manufacturer but with different viscosities
- Biodegradable oils (HEES/HEPG/HETG/HEPR) and mineral oils.

Consequences

- Swelling of elastomers and hydraulic hose lines
- Poorer oil air release properties
- Changes in viscosity
- Increased tendency to foam
- Filter blockages
- Acid formation
- Increased oxidation of the oil
- Reduced efficiency
- Sludge formation, sticking, deposits due to additive reactions
- Oil aging, shorter oil change intervals
- Loss of all rights under the manufacturer's warranty

Recommendations

- Mixing oils should always be avoided because you cannot be 100 % certain that the combination will not lead to problems. This recommendation expressly includes hydraulic fluids with the same classification.
- Monitor oil condition regularly using oil analyses and sensors

Shear

Overloading through excessively high pressures and temperatures destroys the chains of molecules in the hydraulic oil and adversely affects its flow properties.

Causes

- High oil temperatures
- High operating pressures
- Use of the wrong oil

Consequences

- Failure of additives
- Changes in viscosity
- Shorter oil change intervals
- Increased wear on components
- Reduced efficiency

Recommendations

- Use a high-quality oil suitable for the purpose
- Monitor temperature and pressure
- Monitor oil condition regularly using oil analyses and install sensors

HANSA-FLEX brand absorber filter – one of many quality components for your fluid management.

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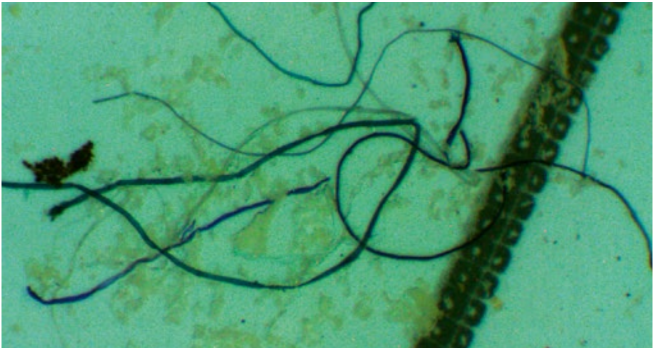
New oil should always be filtered

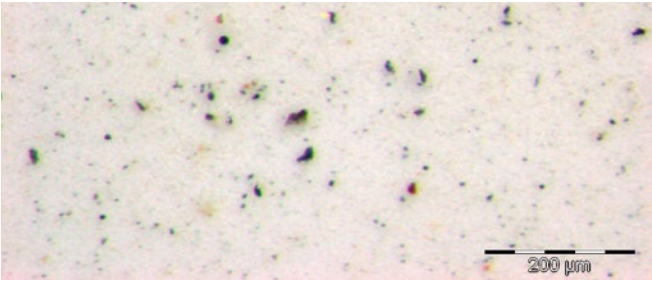
Relying on the cleanliness of new oil can be an expensive mistake, because new oil does not necessarily mean clean oil. It is not infrequently supplied in an unclean state, because oils are not fine-mesh filtered during the production and filling processes. Containers are not always properly cleaned out and may still contain residues from the production process (steel drum) and/or water.

Moreover, solid particles can often get into the oil during filling, decanting and transport. The level of cleanliness of these containers is therefore seldom better than the specified minimum ISO cleanliness code requirement 21/19/16, which in any case is not sufficient for modern hydraulic applications.



100x magnification of a sample of unfiltered HLP 46 fresh oil as supplied in a canister

Minimum requirements for fresh oil DIN 51524



Cleanliness code 21/19/16 in accordance with ISO 4406:1999

Recommended cleanliness code for modern servo-hydraulic systems

Cleanliness code 15/13/10 in accordance with ISO 4406:1999

New oil should always be pre-filtered before being used to fill the machine.

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HANSA-FLEX solutions

HANSA-FLEX Fluid Service offers a broad spectrum of intelligent services and high-quality components for long-term assurance of your fluid quality.

Certified oil analysis performed in the laboratory

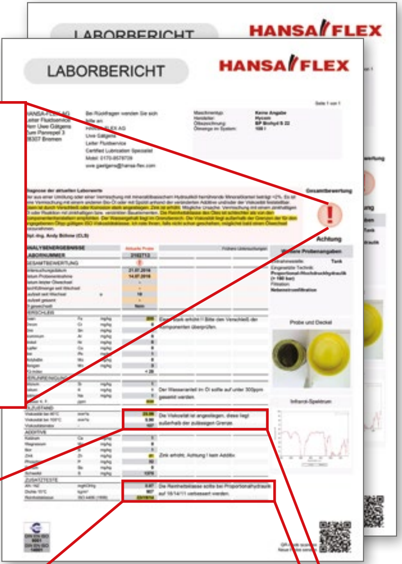
The HANSA-FLEX Fluid Service certified oil analysis reveals all the important information contained in your machine's hydraulic oil, just like a comprehensive blood test. Contamination, mixing and oil aging can be precisely determined.

The analysis is performed by an accredited and certified independent laboratory. The specialists at the HANSA-FLEX Fluid Service interpret the results and add some practical recommendations for future implementation.

Written laboratory reports are normally delivered to the customer within three working days, while an express analysis can be provided in particularly urgent cases. The reports form the basis for all future fluid management procedures. The HANSA-FLEX Mobile Fluid Service can provide immediately available analyses on site anywhere in Germany.

Advantages for the user

- Robust data about the condition of the oil and the machine
- Immediate fault detection associated with oil mixing, contamination and/or water in the oil
- Information about the ideal oil change interval
- Quality control after switching to a different oil
- Warranty cover and warranty services

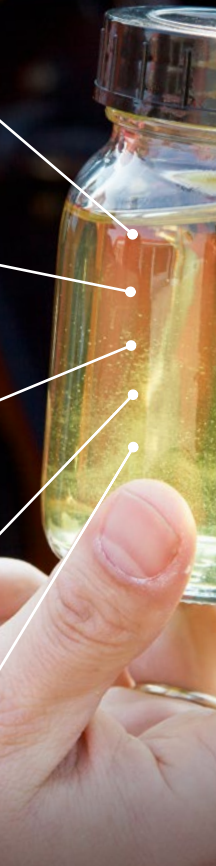


The water content is close to the limit. The viscosity is outside the limits for the specified ISO viscosity class for the given oil type. I would advise you to change the oil as soon as possible, unless you have already done it.

25.59 5.90 187	**The viscosity is increased. This is outside the permissible limit.**

0.87 907 23/19/14	**The cleanliness code for proportional hydraulics should be improved to 16/14/11.**

The 10 golden rules of hydraulic oil care



1. Select a high-quality hydraulic oil suitable for its intended purpose!

2. Flush the hydraulic system completely before bringing it into use!

3. Always pre-filter new oil!

4. Never mix oils!

5. Avoid contaminating oil with air, water or solid particles!

6. Have regular oil tests performed in the laboratory or on site!

7. Use high-quality filter systems and elements!

8. Avoid thermal overload of the oil!

9. Avoid contamination occurring during assembly or installation!

10. Monitor oil condition continuously using sensors. Install an online condition monitoring system!

Damage detection and fluid-related system optimisation by specialists in oil and hydraulics

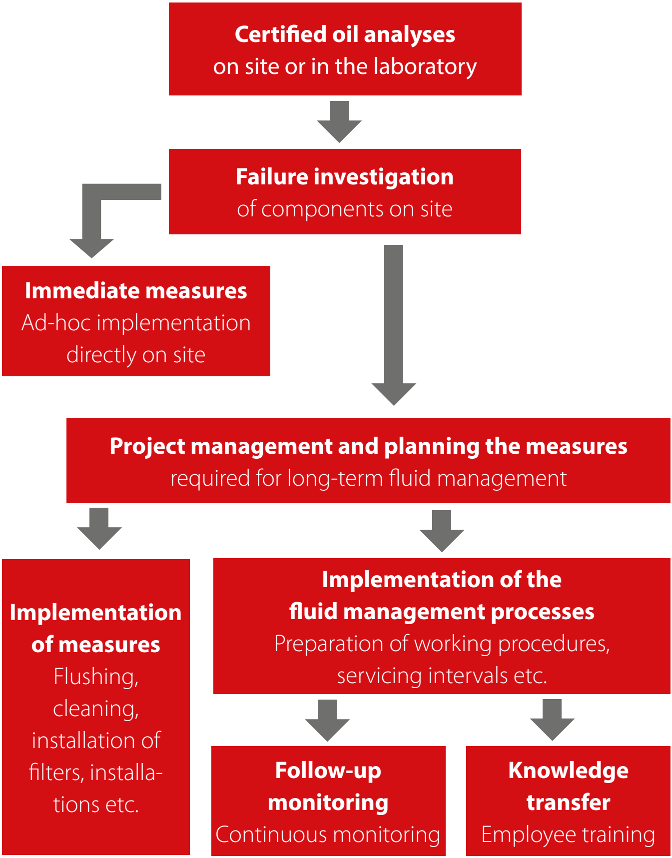
In the event of damage, experienced fluid and hydraulic specialists from the HANSA-FLEX Fluid Service immediately set about determining the cause of the damage.

Approach:

Using the findings of a certified oil analysis, the resulting actions may include:

- Failure investigations of the hydraulic plant or equipment, looking for damage on components, e.g.: damage to pumps, hydraulics, motors and cylinders, damage to hydraulic hose lines and hydraulic filters
- Project management and planning the required work with the customer – one-off measures to rectify faults or regular preventative maintenance
- Long-term optimisation of fluid management of the hydraulic plant or equipment to improve performance, avoid damage and lengthen oil change intervals.

360° fluid management



HANSA-FLEX brand fluid cleaning equipment

High-performance equipment for fluid cleaning in mobile and stationary hydraulic systems – rental, sales and service

- Partial flow filter systems from 2 to 150 litres/min
- Partial flow filter systems for flame-resistant oils
- Vacuum dewatering systems up to 90 litres/hour
- Flushing containers/high-performance flushing units from 50 to 1,050 litres/min

Individualised design and manufacture
for lasting installation in hydraulic systems

HANSA-FLEX flushing unit

HANSA-FLEX partial flow filter system


HANSA FLEX
HANSA-FLEX HD 210
BAR
BAR

Condition monitoring

Oil condition sensors are used to continuously monitor hydraulic systems and drives.

They allow you to:

- Detect malfunctions in operating systems quickly
- Increase operational reliability
- Long-term and need-related maintenance interval planning
- Reduce the risk of system failure
- Collect contemporary data, record and archive it for long-term use

! Early detection of reaching limit values saves money!

Our range of services:

- Present state analysis and basic planning
- Definition of limit values in the context of system specific requirements
- Selection and installation of oil condition sensors
- Configuration and establishment of the required data transmission routes
- Evaluation and interpretation of the measured values
- Manufacture and installation of system specific control cabinets, alarm devices etc.

Continuous monitoring of the oil condition using sensors

Continuous collection of data
Information about: viscosity, solid particles, oil levels, relative humidity, relative permittivity, conductivity, temperature, pressure

Local interface
Display of measured values and visual or acoustic warning signal when limit values are exceeded

Worldwide data transfer
All data are available from anywhere in the world at any time

Control of water sensors on a plastic injection moulding machine

Mobile Fluid Service – available for you on site

Performance of fluid service work on mobile and industrial hydraulics systems

- Collection of oil samples in accordance with the standards for oil analyses on site or in the laboratory
- Filtering of oils in hydraulic systems and drives
- Installation and maintenance of partial flow filter systems
- Design and manufacture of filter systems
- Dewatering of oils in hydraulic systems and drives
- Flushing all pipelines and components including documentation in accordance with ISO 4406:1999
- Switching to a different type of oil
- Optimising filter systems
- Monitoring/optimisation of hydraulic systems
- Commissioning of hydraulic systems
- Preparation of measurement records of pressure, pressure peaks, volumetric flow, speed of revolution and temperature
- Design and installation of oil condition sensors
- Documentation of all measured values, and provision of advice

Immediate fault detection

- In the event of oil mixing, oil contamination, water in the oil
- Damage detection on components, e.g. pump damage, damage to hydraulic systems, motors, and cylinders, hose lines, hydraulic filters etc.

Fluid Service vehicles

- Mobile oil analysis vehicle for rapid oil analyses on site
- Visual analysis of solid particles to determine material using a microscope, membranes and particle photography
- Determination of the cleanliness class in accordance with ISO, SAE, NAS
- Determination of the viscosity, temperature, relative humidity
- Determination of the water content and the oxidation of the hydraulic oil using the hydrogen gas method (water test kit)

Mobile oil analysis vehicle for rapid oil analyses, fault detection and oil servicing on site

Pre-filtering of new oil – for you directly on site

Our service for machine operators and lubricant dealers ensures that the supplied fresh oil complies with the necessary cleanliness classification.

- Mobile analysis of the supplied new oil performed on site
- Immediate filtration of the oil to achieve the desired cleanliness code
- Recording and documentation of the cleanliness code directly on site
- On request, scheduling and coordination of activities with the oil supplier and machine operator

Quality components for your fluid management

Articles are always available at **shop.hansa-flex.com** and in our branches:

Analysis equipment

- Fluid sampling kits: dynamic, stationary
- Oil analysis: Particle counters, inline particle sensors
- Oil analysis kits for mineral oil, bio oil, gear oil, flame-resistant oils, turbine oil, compressor oil, grease and diesel fuel

Filters & accessories

- Filter elements for partial flow filter systems
- Oil service devices
- Wide range of filters: suction filters, return flow filters, spin-on filters, tank ventilation filters, absorber filters

Sensors

- Particle monitors
- Water sensors, viscosity sensors, oil condition sensors, oil level sensors
- Pressure-boosting pumps for installation in tanks

Everything an oil has to do

Hydraulic oil is a highly complex element of any system and has to cope with a wide range of severe loadings in continuous use. The pressure fluids standard DIN 51524 specifies only the minimum requirements for the basic properties of hydraulic fluids. In addition to these properties, hydraulic fluids have to satisfy additional requirements in special areas of use.

Shear stability

Ability to be filtered

Low hygroscopicity

Resistance to thermal loads

Oxidation stability

Compatibility with materials

Lubrication and protection against wear

Viscosity stability

Low thermal expansion

Corrosion protection properties

Ability to conduct heat

Low foaming

Good air release properties and low air absorption

Market-standard hydraulic oils

The quality and cleanliness of the hydraulic oils used are crucial factors for operational reliability, durability and the efficient operation of hydraulic systems. The following tables give a brief overview of commonly available oil types, their properties and fields of use. The machine manufacturer's requirements must be observed in the choice of oils. You are recommended to seek urgent competent advice from hydraulic oil experts, lubricant manufacturers or dealers about the choice and care of hydraulic oil.

Overview of mineral-based hydraulic oils		
Oil type	Short description	Uses
H	Plain oil (no additives)	Practically none
HL In acc. with DIN 51524-1	Aging and corrosion protection additives	Very few
HLP In acc. with DIN 51524-2	Like HL, additional viscosity index improver and high-pressure additives	Today's minimum requirement
HLPD based on DIN 51524-2	Like HLP, additional detergent + dispersant action	Moist environment, intermittent operation (on-off)
HVLP In acc. with DIN 51524-3	Like HLP, additional viscosity index improver	Where a wider temperature range is required
HLPD based on DIN 51524-3	Like HVLP, additional detergent + dispersant action	Wider temperature range, moist environment, intermittent operation

Types of hydraulic oils for specialised fields of use		
Field of use	Special requirements	Oil type
Metal foundries	Flame resistant	HFC 46 HFD 46
Mobile hydraulics equipment in nature conservation areas	Rapidly biodegradable	HEES 46
Mobile cableway hydraulic systems	Very good V-T behaviour, very good corrosion protection	HVLP 46 HVLPD 46
Stationary hydraulic systems	Improved compatibility with coolant lubricants	HLPD 46
Food industry hydraulic systems	Harmless to human health	Hydraulic oil in acc. with NSF H1 or H2

Cleanliness codes of hydraulic fluids

Continually rising requirements for reliability, availability and efficiency of hydraulic systems require not only ever-cleaner hydraulic fluids but also their precise monitoring and control. The classification of the degree of cleanliness (level of contamination) or the cleanliness code of hydraulic fluids is done by counting the number of solid particles they contain.

In addition to the size of the particles, their number is also determinant for the amount of wear in a system. Not every particle damages the system, but the lower the number of all the critical particles, the less likely the components are to be damaged.

The standards used to classify the cleanliness of hydraulic fluids are **ISO 4406:1999** and **SAE AS 4059. NAS 1638** is no longer up-to-date and has been superseded by SAE AS 4059.

In **ISO 4406:1999**, particle numbers are determined cumulatively and assigned to various range codes. The range codes show the particle numbers in specific size classes, where each size class covers a specific range of particle sizes of the particles counted.

In accordance with ISO 4406:1999, the cleanliness codes are expressed as a series of three numbers, which represent the particle count ranges determined for each **particle size class ≥ 4 µm / ≥ 6 µm / ≥ 14 µm**.

ISO 4406/1999

ISO 4406:1999 / Code chart for particulate contamination of hydraulic oils		
Particles per 100 ml		ISO range code
More than	Up to and including	
130,000,000	250,000,000	**28**
64,000,000	130,000,000	**27**
32,000,000	64,000,000	**26**
16,000,000	32,000,000	**25**
8,000,000	16,000,000	**24**
4,000,000	8,000,000	**23**
2,000,000	4,000,000	**22**
1,000,000	2,000,000	**21**
500,000	1,000,000	**20**
250,000	500,000	**19**
130,000	250,000	**18**
64,000	130,000	**17**
32,000	64,000	**16**
16,000	32,000	**15**
8,000	16,000	**14**
4,000	8,000	**13**
2,000	4,000	**12**
1,000	2,000	**11**
500	1,000	**10**
250	500	**9**
130	250	**8**
64	130	**7**
32	64	**6**
16	32	**5**

The ISO cleanliness code 16/14/11 represents the minimum requirements for modern proportional hydraulics.

A cleanliness code of **ISO 16/14/11** means that a sample of oil contains

- **32,000 to 64,000 particles ≥ 4 µm**
- **8,000 to 16,000 particles ≥ 6 µm**
- **1,000 to 2,000 particles ≥ 14 µm**

per 100 ml.

SAE AS 4059F

Cleanliness classes in accordance with SAE AS 4059F							
Maximum permissible number of particles per 100 m for each cleanliness class							
Cleanli-ness class	(1)	>1 µm	>5 µm	>15 µm	>25 µm	>50 µm	>100 µm
	(2)	> 4 µm(c)	> 6 µm(c)	> 14 µm(c)	> 21 µm(c)	> 38 µm(c)	> 70 µm(c)
000		195	76	14	3	1	0
00		390	152	27	5	1	0
0		780	304	54	10	2	0
1		1,560	609	109	20	4	1
2		3,120	1,217	217	39	7	1
3		6,250	2,432	432	76	13	2
4		12,500	4,864	864	152	26	4
5		25,000	9,731	1,731	306	53	8
6		50,000	19,462	3,462	612	106	16
7		100,000	38,924	6,924	1,224	212	32
8		200,000	77,849	13,849	2,449	424	64
9		400,000	155,698	27,698	4,898	848	128
10		800,000	311,396	55,396	9,796	1,696	256
11		1,600,000	622,792	110,792	19,592	3,392	512
12		3,200,000	1,245,584	221,584	39,184	6,784	1,024

(1) Size range, optical microscope, based on the largest measured length in accordance with AS598 or ISO 4407.

(2) Size range, automatic particle counter calibrated in accordance with ISO 11171 or an optical or electron microscope with image analysis software, based on the equivalent diameter of the projected area.

NAS 1638

Cleanliness classes in accordance with NAS 1638					
Cleanliness class	Number of particles per 100 ml				
	5 - 15 µm	15 - 25 µm	25 - 50 µm	50 - 100 µm	> 100 µm
00	125	22	4	1	0
0	250	44	8	2	0
1	500	89	16	3	1
2	1,000	178	32	6	1
3	2,000	356	63	11	2
4	4,000	712	126	22	4
5	8,000	1,425	253	45	8
6	16,000	2,850	506	90	16
7	32,000	5,700	1,012	180	32
8	64,000	11,400	2,025	360	64
9	128,000	22,800	4,050	720	128
10	256,000	45,600	8,100	1,440	256
11	512.00	91,200	16,200	2,880	512
12	1,024,000	182,400	32,400	5,760	1,024

Recommended cleanliness classes and filter units for selected hydraulic applications

The more complex and finely detailed the hydraulic system is designed to be, the higher are the requirements for the cleanliness of the hydraulic fluids and the installed filters. The following table gives an overview of current guidance values, but cannot in any way replace the need to make individualised observations on each system.

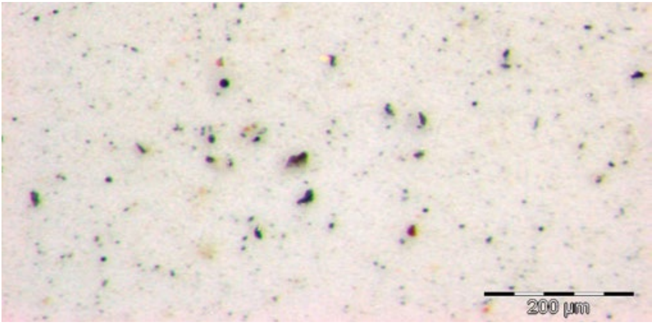
!

The recommended cleanliness classes relate to an operating pressure of up to 160 bar.
If higher operating pressures are involved, a better cleanliness class should be adopted.

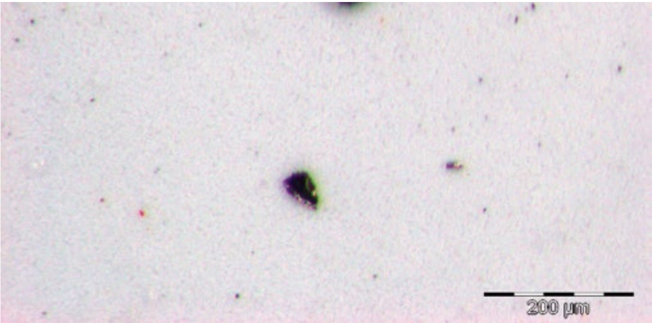
The cleanliness code ISO 21/19/16 is the minimum requirements for fresh oil in accordance with DIN 51524. This is no longer in accordance with modern custom and practice for most hydraulic applications.

Hydraulic system and field of application	Permissible cleanliness classes			Recom-mended filter mesh size (x) (Absolute) (x) µm = > βx >100
	ISO 4406:1999 >160 bar ISO code ≥4 µm/ ≥6 µm/ ≥14 µm	**SAE AS 4059** ISO code >4 µm/>6 µm/ >14 µm/21 µm/ >38 µm/70 µm	**NAS 1638** NAS code 5 – 15 µm	
Laboratory and aircraft engineering Systems with servo hydraulics, test bed hydraulics • Servo valves	≤ 15 / 13 / 10	≤ 5	≤ 4	2 – 3 µm
Industrial hydraulics, proportional hydraulics, high-pressure and lubricant systems • Modern construction & forestry machinery • Plastic injection moulding machines • Proportional valves	≤ 16 / 14 / 11	≤ 6	≤ 5	3 – 5 µm
Industrial hydraulics, electromagnetic control valves, medium-low pressure systems • Older construction & forestry machinery • Municipal utility vehicles, agricultural machines • Recycling plants • Solenoid valves	≤ 19 / 17 / 14	≤ 9	≤ 8	5 – 10 µm
General medium-pressure hydraulic systems of the average size, low pressure systems with large internal clearances and low requirements for wear protection, also water-based hydraulic systems in the high-pressure range with high (large particle size) contamination loads	≤ 21 / 19 / 16	≤ 11	≤ 10	10 – 20 µm

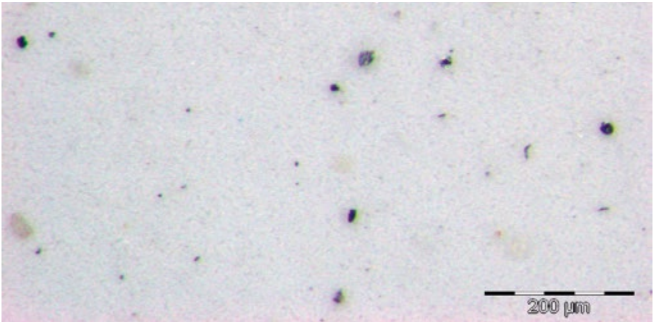
Examples of ISO 4406:1999 cleanliness classes



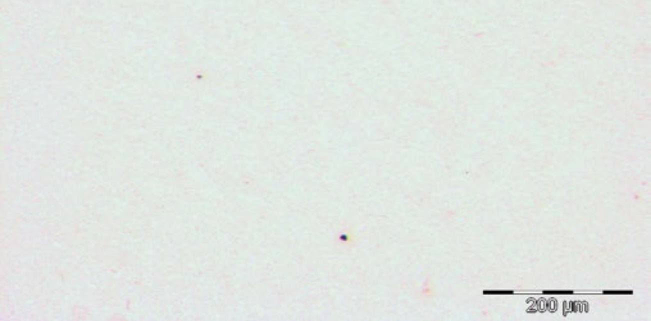
ISO code 21/19/16 – the minimum requirement for fresh oil supplied in accordance with DIN 51524



ISO code 16/14/11 – requirement for proportional valves



ISO code 19/17/14 – requirement for electromagnetic control valves



ISO code 15/13/10 – requirement for proportional valves

Viscosity of hydraulic oils

Viscosity is one of the most important physical characteristics of hydraulic fluids. It is the measure of the internal friction of an oil when flowing. Cold oil has a high internal friction (high viscosity). As the oil becomes warmer, the internal friction reduces (lower viscosity). The permissible viscosity range is calculated based on all the installed components of the hydraulic system and must be maintained appropriately for each individual component.

The kinematic viscosity is expressed in mm^2/s. Lubricating oils that are not engine oils or gearbox oils are specified in terms of ISO-VG (International Organisation for Standardization Viscosity Grades). There are 18 viscosity classes in the standard ranging from 2 mm^2/s to 1,500 mm^2/s. The viscosity specified here is only an average value.

Recommended viscosity ranges of the ISO viscosity classes in accordance with DIN ISO 3448 (2010), reference temperature 40 °C	
Viscosity class (ISO)	Viscosity range mm^2/s (cSt) at 40 °C
ISO VG 22	19.8 – **22** – 24.2
ISO VG 32	28.8 – **32** – 35.2
ISO VG 46	41.4 – **46** – 50.6
ISO VG 68	61.2 – **68** – 74.8
ISO VG 100	90 – **100** – 110

If the permissible operating viscosity is set too high, this can lead to hydraulic and mechanical wear. Pumps may be damaged by cavitation if the actual pressure is less than the permissible suction pressure.

If the viscosity is less than the permissible operating viscosity, the result may be increased leakage and component wear. Components may then have a shorter working life.

The upper limit of viscosity for a cold start of a machine is normally 500-1,000 mm^2/s. The lower limit of viscosity is approximately 10 mm^2/s, after which the fluid can no longer provide a lubricating effect because it is flowing too thinly.

Depending on the use of the hydraulic system, its field of application and oil type, the limiting values of the measured viscosities may be between 5 and 15 % of the recommended viscosity range.

If a large change in viscosity occurs, it is essential to change the oil.

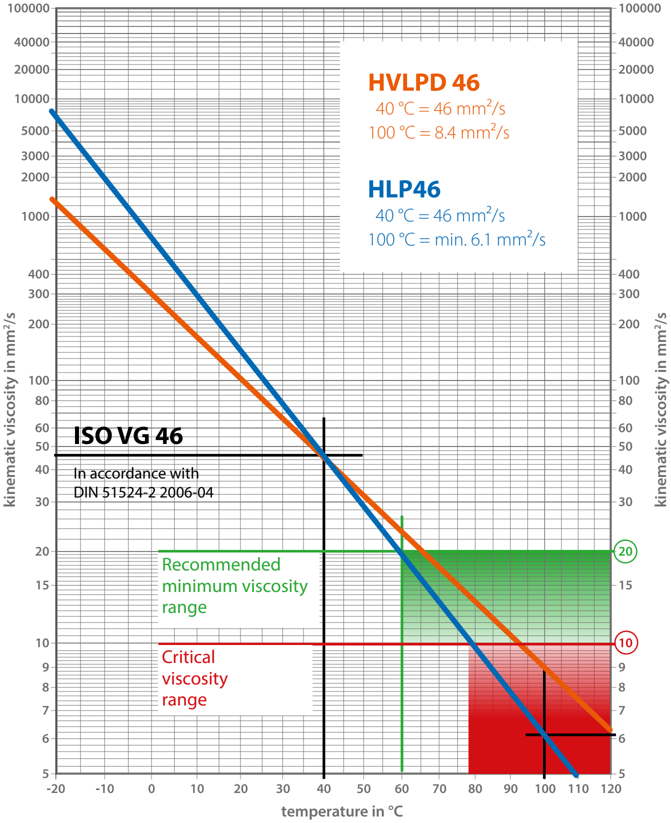
Viscosity-temperature diagram

The viscosity-temperature diagram (V-T diagram) is used to represent the viscosity-temperature behaviour of hydraulic oils. The viscosity for any temperature can be read off the diagram by drawing a straight line between two points (normally 40° C and 100° C). This allows the various ranges of use to be defined for different oil types.

The chart on the right compares the viscosity-temperature behaviour of two hydraulic oils. The area coloured **green** represents the minimum viscosity of 10 – 20 mm^2/s recommended by most machine manufacturers.

Explanation of use: **HVLPD 46**, represented by the orange line, enters the critical viscosity range at a temperature of approximately 90 °C, while the blue **HLP 46** oil has already reached the critical range at approximately 80° C.

If a hydraulic oil enters the critical range, its lubricating effect is reduced, which results in damage to machinery. Normally the manufacturer will reject claims under the warranty for the above type of damage where it can be proven that the viscosity dropped below the minimum permissible value.


HVLPD 46
40 °C = 46 mm²/s
100 °C = 8.4 mm²/s
HLP46
40 °C = 46 mm²/s
100 °C = min. 6.1 mm²/s
ISO VG 46
In accordance with
DIN 51524-2 2006-04
Recommended minimum viscosity range
Critical viscosity range
20
10
kinematic viscosity in mm²/s
temperature in °C
100000
40000
20000
10000
5000
3000
2000
1000
400
300
200
100
80
60
50
40
30
20
15
10
9
8
7
6
5
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120

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