HYDAC FILTER SYSTEMS

Fluid controlling
Contamination handbook

EN 7.603.12/12.24

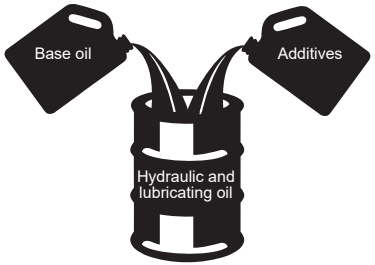
Classification of base oils according to API 1509*

	API* Group			
	I	II	III	IV
Oil type	Refined product	Hydrogen-ated base oil	Synthetic oil	PAO
Percentage of satu-rated hydrocarbons	< 90%	> 90%	> 90%	100%
Viscosity index	80 – 120	80 – 120	> 120	–
Polarity	High polarity	Less polar	Almost non-polar	Not specified
Solubility of varnish	High	Medium	Weak	Weak
Conductivity	Good	Bad	Very low	Low

* American Petroleum Institute (API)

Composition of hydraulic and lubricating oils

Hydraulic and lubricating oil = **Base oil** + **Additives***



*** Examples of additives:**
– VI improver
– Pour point reducer
– Oxidation inhibitor
– Corrosion inhibitor
– Anti-wear
– Anti-foam

Classification of hydraulic oils according to DIN

Hydraulic fluid	Abbreviation	Density at 15 °C (kg/m³)
Mineral oil according to DIN 51524 or ISO 11158	H, HL, HLP, HV, HLPD	860
Fire resistant according to DIN 5150 or ISO 12922	HFA / HFB	1,000
	HFC	1,090
	HFDR, HFDS	1,200
Rapidly biodegradable according to ISO 15380	HETG	930
	HEES	940
	HEPG	1,100
	HEPR	890
Lubricating oils according to DIN 51517	CL, CLP, CG	860

Food-grade oils according to NSF International

H1 lubricant	'Food-grade (FG) lubricants' 'Food-grade oil' Safe for technically unavoidable, occasional food contact
H2 lubricant	Food contact not permitted. Use only outside the closed production process
H3 lubricant	Soluble oils for machine cleaning or rust protection

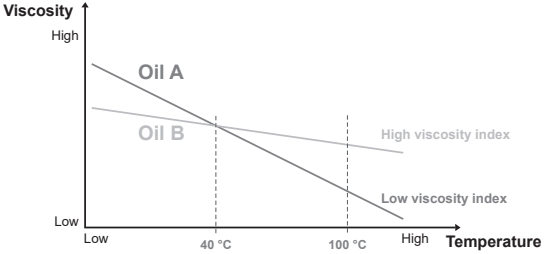
Viscosity – ISO / SAE comparison

ISO VG (DIN 51519)	Centre point viscosity (40°C) and approx. viscosities in mm²/s at				Approximate allocation of the	
	0°C	40°C	50°C	100°C	Engine oils SAE	Automotive transmission oils SAE
5	8 (1.7 E)	4.6	4	1.5		
7	12 (2 E)	6.8	5	2.0		
10	21 (3 E)	10	8	2.5		
15	34	15	11	3.5	5 W	
22	55	22	15	4.5	10 W	70 W
32	88	32	21	5.5		75 W
46	137	46	30	6.5	15 W	
68	219	68	43	8.5	20 W	80 W
100	345	100	61	11	30	
150	550	150	90	15	40	85 W
220	865	220	125	19	50	90
320	1,340	320	180	24		
460	2,060	460	250	30		140
680	3,270	680	360	40		
1,000	5,170	1,000	510	50		250
1,500	8,400	1,500	740	65		

Viscosity index according to ISO 2909 –

Comparison of two mineral oils

The higher an oil's viscosity index, the less its viscosity changes at different temperatures.



Types of contamination

Solid contamination

– Corundum, scale, rust particles
– Wear metals: iron, copper, tin, zinc, etc.
– Fibres, rubber particles, paint particles

Liquid contamination

– Coolant
– Steam

Gel-like contamination

– Oil ageing / varnish
– Oil mixtures
– Additive segregation (dropout)

Gaseous contamination

– Air
– Process gases

Causes of contamination in the oil

	Cause
Solid	– Assembly contamination – Environmental pollution – Topping up hydraulic fluid – Internal wear processes – Oil ageing
Liquid	– Humidity from the ambient air – Leaks from the cooler – Process water / process steam – Leaks from the seals – High-pressure cleaner – Chemical processes (combustion, oxidation, neutralisation)
Gel-like	– Oil ageing – Oil mixing
Gaseous	– Mixtures – Outgassing the oil

Consequences of contamination

	Consequences
Solid	– Abrasive wear – Increased leakage – Component failure – Loss of control accuracy – Control spool blockage – Short fluid lifetime
Liquid	– Corrosion – Reduction in dynamic viscosity • Reduction in lubricating film thickness • Contact with surfaces • Wear – Change in oil consistency • Formation of acidic oil ageing products • Formation of sludge • Increase in the oil ageing rate – Cavitation damage
Gel-like	– Reduction in lubrication gaps due to deposits • Increased friction and temperature • Increased bearing wear – Malfunctions in valves • Unstable control behaviour – Damage to dynamic seals • Leaks – Filter element blockage • Short filter lifetimes due to sludge formation – Increased storage temperature due to caking
Gaseous	– Cavitation – Oxidation – Localised oil overheating • Increase in the oil ageing rate • Loss of control accuracy

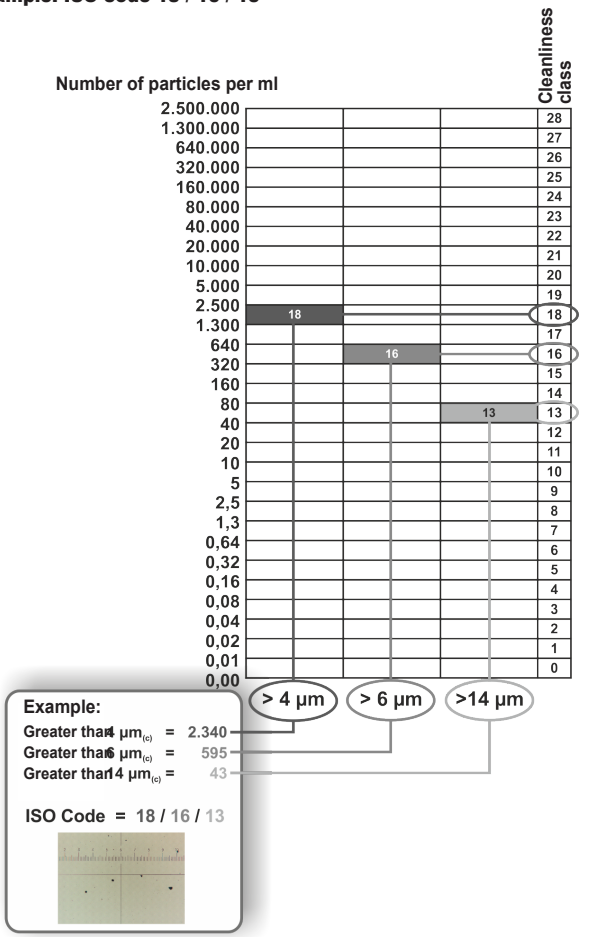
Cleanliness classes according to ISO 4406

ISO code determination

In ISO 4406, the particle counts are determined cumulatively (i.e. > 4 µm $_{(c)}$, > 6 µm $_{(c)}$ and > 14 µm $_{(c)}$) (manually by filtering the liquid through an analysis membrane or automatically with particle counters) and assigned metrics.

ISO class	Particle count / 100 ml		Dirt level (ACFTD)
	More than	Up to and including	[mg/l]
0	0.5	1	–
1	1	2	–
2	2	4	–
3	4	8	–
4	8	16	–
5	16	32	–
6	32	64	0.001
7	64	130	–
8	130	250	–
9	250	500	–
10	500	1,000	0.01
11	1,000	2,000	–
12	2,000	4,000	–
13	4,000	8,000	0.1
14	8,000	16,000	–
15	16,000	32,000	0.2
16	32,000	64,000	0.5
17	64,000	130,000	1
18	130,000	250,000	3
19	250,000	500,000	5
20	500,000	1,000,000	7 / 10
21	1,000,000	2,000,000	20
22	2,000,000	4,000,000	40
23	4,000,000	8,000,000	80
24	8,000,000	16,000,000	–
25	16,000,000	32,000,000	–
26	32,000,000	64,000,000	–
27	64,000,000	130,000,000	–
28	130,000,000	250,000,000	–
> 28	250,000,000		

Example: ISO code 18 / 16 / 13



Cleanliness classes according to SAE AS 4059

Like ISO 4406, SAE AS 4059 describes particle concentrations in liquids. The analysis methods can be used analogous to ISO 4406 and NAS 1638.

The SAE cleanliness classes are based on particle size, number and particle size distribution. As the determined particle size depends on the measuring method and the calibration, the particle sizes are labelled with letters (A – F).

		Max. particle concentration (particles / 100 ml)					
ISO 4402 size Calibration or opt. count*		> 1 µm	> 5 µm	> 15 µm	> 25 µm	> 50 µm	> 100 µm
ISO 11171 size, calibration or electron microscope**		> 4 $\mu m_{(c)}$	> 6 $\mu m_{(c)}$	> 14 $\mu m_{(c)}$	> 21 $\mu m_{(c)}$	> 38 $\mu m_{(c)}$	> 70 $\mu m_{(c)}$
Size coding		**A**	**B**	**C**	**D**	**E**	**F**
Contamination classes	**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	1,220	217	39	7	1
	3	6,250	2,430	432	76	13	2
	4	12,500	4,860	864	152	26	4
	5	25,000	9,730	1,730	306	53	8
	6	50,000	19,500	3,460	612	106	16
	7	100,000	38,900	6,920	1,220	212	32
	8	200,000	77,900	13,900	2,450	424	64
	9	400,000	156,000	27,700	4,900	848	128
	10	800,000	311,000	55,400	9,800	1,700	256
	11	1,600,000	623,000	111,000	19,600	3,390	512
	12	3,200,000	1,250,000	222,000	39,200	6,780	1,020

* Particle sizes determined according to the longest expansion
** Particle sizes determined according to the diameter of the projected circle of equal area

Cleanliness classes according to NAS 1638

Like ISO 4406 and SAE AS 4059, NAS 1638 describes particle concentrations in liquids. Although this standard is no longer valid as a norm, it is often used in practice as it is easy to use (only one metric).

The analysis methods can be used analogous to ISO 4406.

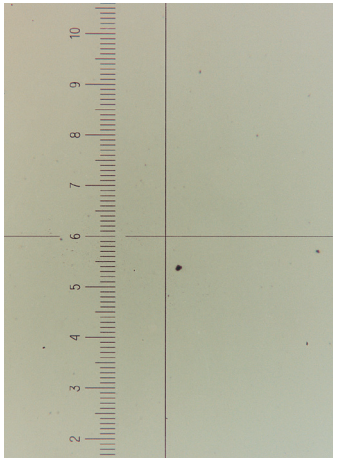
In contrast to ISO 4406, certain particle size ranges are counted in NAS 1638 and assigned to these metrics.

Number of particles in 100 ml sample

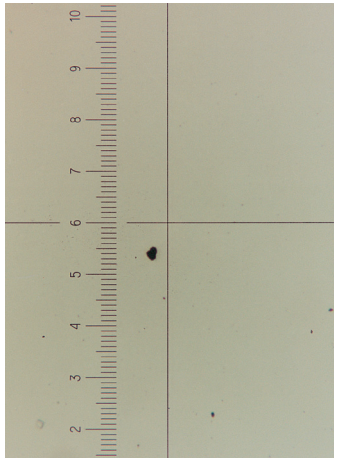
		Particle size (µm)				
		5 – 15	15 – 25	25 – 50	50 – 100	> 100
Cleanliness classes	00	125	22	4	1	0
	0	250	44	8	2	0
	1	500	89	16	3	1
	2	1,000	178	32	6	1
	3	2,000	356	63	11	2
	4	4,000	712	126	22	4
	5	8,000	1,425	253	45	8
	6	16,000	2,850	506	90	16
	7	32,000	5,700	1,012	180	32
	8	64,000	11,600	2,025	360	64
	9	128,000	22,800	4,050	720	128
	10	256,000	45,600	8,100	1,440	256
	11	512,000	91,200	16,200	2,880	512
	12	1,024,000	182,400	32,400	5,760	1,024

Comparison photo for contamination classes

ISO 4406 Class 14 / 12 / 9
SAE AS 4059 Class 4
NAS 1638 Class 3

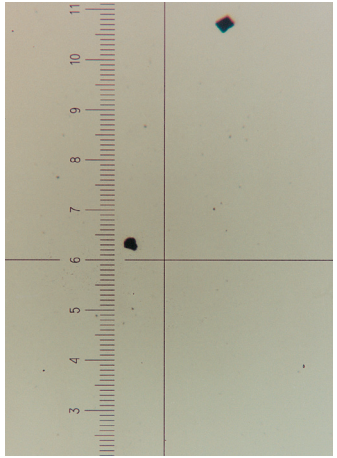


ISO 4406 Class 15 / 13 / 10
SAE AS 4059 Class 5
NAS 1638 Class 4

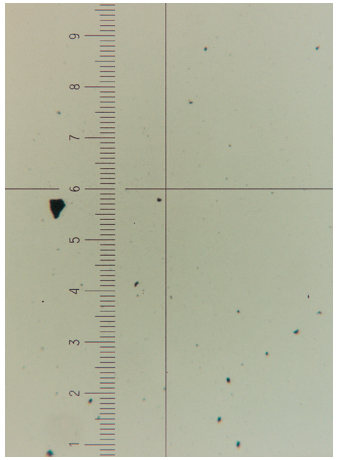


Increase: 100-fold
Volume of oil: 100 ml
1 scale mark = 10 µm

ISO 4406 Class 16 / 14 / 11
SAE AS 4059 Class 6
NAS 1638 Class 5

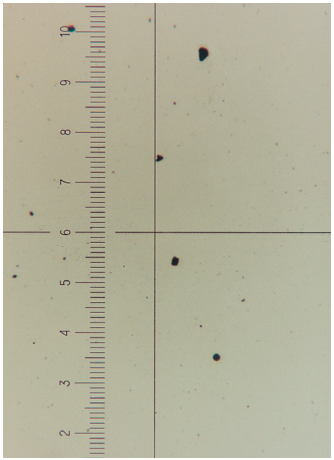


ISO 4406 Class 17 / 15 / 12
SAE AS 4059 Class 7
NAS 1638 Class 6

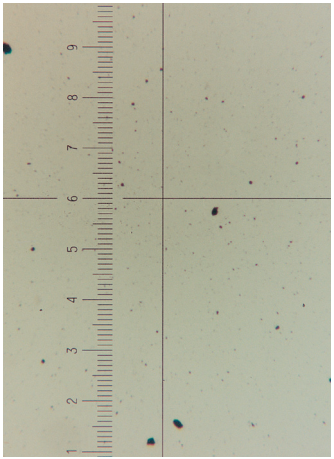


Increase: 100-fold
Volume of oil: 100 ml
1 scale mark = 10 µm

ISO 4406 **Class 18 / 16 / 13**
SAE AS 4059 **Class 8**
NAS 1638 **Class 7**

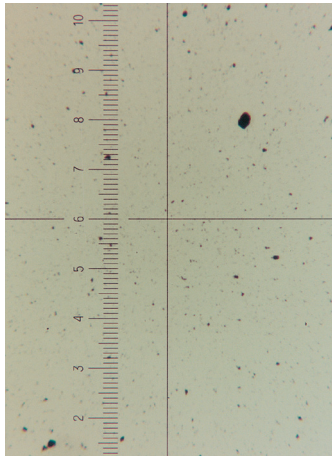


ISO 4406 **Class 19 / 17 / 14**
SAE AS 4059 **Class 9**
NAS 1638 **Class 8**

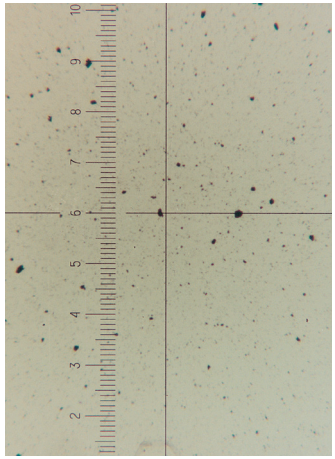


Increase: 100-fold
Volume of oil: 100 ml
1 scale mark = 10 µm

ISO 4406 **Class 20 / 18 / 15**
SAE AS 4059 **Class 10**
NAS 1638 **Class 9**

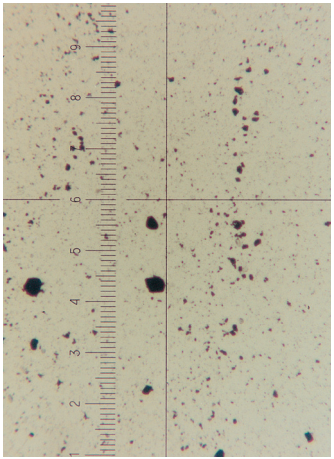


ISO 4406 **Class 21 / 19 / 16**
SAE AS 4059 **Class 11**
NAS 1638 **Class 10**

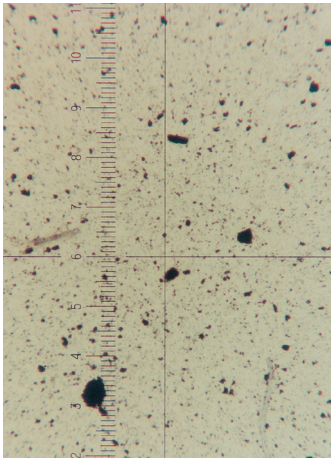


Increase: 100-fold
Volume of oil: 100 ml
1 scale mark = 10 µm

ISO 4406 **Class 22 / 20 / 17**
SAE AS 4059 **Class 12**
NAS 1638 **Class 11**



ISO 4406 **Class 23 / 21 / 18**
SAE AS 4059 **Class 13**
NAS 1638 **Class 12**



Increase: 100-fold
Volume of oil: 100 ml
1 scale mark = 10 µm

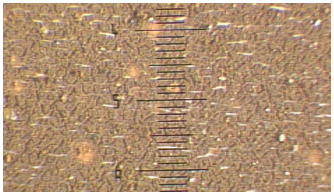
Examples of solid contamination

Predominantly rust, additives (white particles)

Impact:
– Severe oil ageing
– Malfunctions at pumps, valves
– Wear, mostly water in oil

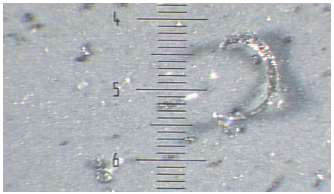
Oil ageing products

Impact:
– Filter blocking
– System silting-up



Metal chip (flow chip)

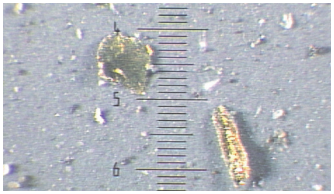
Impact:
– Malfunctions at pumps, valves
– Seal wear
– Leakage
– Oil ageing



Increase: 48-fold
1 scale mark = 45 µm

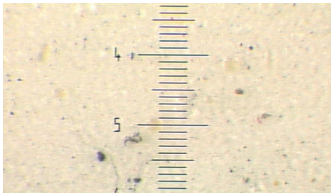
Particles or chips of bronze, brass or copper

Impact:
– Malfunctions at pumps, valves
– Oil ageing
– Leaks
– Seal wear



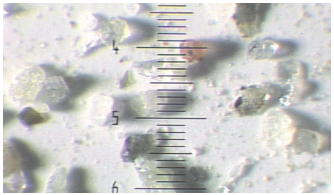
Gel-like residue

Impact:
– Filter blocking
– System silting-up



Silicates due to missing or insufficient vent filters

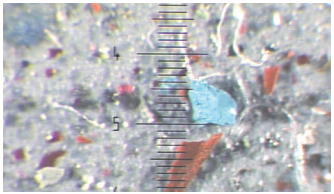
Impact:
– Severe wear on components
– Malfunctions at pumps, valves
– Seal wear



Increase: 48-fold
1 scale mark = 45 µm

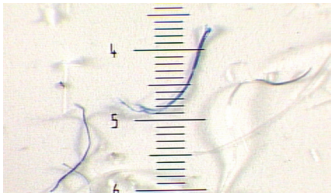
Paint particles (red / brown) Plastic particles (blue)

Impact:
– Malfunctions at pumps, valves
– Seal wear



Fibres due to initial contamination, open tank; cleaning cloths, etc.

Impact:
– Orifice blockage
– Leaks from poppet valves



Increase: 48-fold
1 scale mark = 45 µm

Cleanliness requirements for hydraulic and lubricating oils

	Low / medium pressure < 140 bar (moderate conditions)		High pressure 140 – 200 bar (low / medium under poor conditions[1])		Very high pressure > 200 bar (high pressure under poor conditions[1])	
	ISO 4406 Target cleanliness class	Filtration rating in µm	ISO 4406 Target cleanliness class	Filtration rating in µm	ISO 4406 Target cleanliness class	Filtration rating in µm
Pumps / motors						
Gears or vanes	20 / 18 / 15	20	19 / 17 / 14	10	18 / 16 / 13	5
Pistons	19 / 17 / 14	10	18 / 16 / 13	5	17 / 15 / 12	3
Variable vanes	18 / 16 / 13	5	17 / 15 / 12	3	Not required	Not required
Variable piston	18 / 16 / 13	5	17 / 15 / 12	3	16 / 14 / 11	3 [2]
Drives						
Cylinders	20 / 18 / 15	20	19 / 17 / 14	10	18 / 16 / 13	5
Hydrostatic drives	16 / 15 / 12	3	16 / 14 / 11	3 [2]	15 / 13 / 10	3 [2]
Test rigs	15 / 13 / 10	3 [2]	15 / 13 / 10	3 [2]	15 / 13 / 10	3 [2]
Valves						
Check valve	20 / 18 / 15	20	20 / 18 / 15	20	19 / 17 / 14	10
Directional valve	20 / 18 / 15	20	19 / 17 / 14	10	18 / 16 / 13	5
Standard flow control valve	20 / 18 / 15	20	19 / 17 / 14	10	18 / 16 / 13	5
Poppet valve	19 / 17 / 14	10	18 / 16 / 13	5	17 / 15 / 12	3
Proportional valve	17 / 15 / 12	3	17 / 15 / 12	3	16 / 14 / 11	3 [2]
Servo valve	16 / 14 / 12	3 [2]	16 / 14 / 11	3 [2]	15 / 13 / 10	3 [2]
Bearings						
Friction bearings [3]	18 / 15 / 12	10	Not required	Not required	Not required	Not required
Transmission [3]	17 / 15 / 12	10	Not required	Not required	Not required	Not required
Ball bearings [3]	15 / 13 / 10	3 [2]	Not required	Not required	Not required	Not required
Roller bearings [3]	16 / 14 / 11	5	Not required	Not required	Not required	Not required

Diesel cleanliness requirements

	ISO 4406 target cleanliness class	Filtration rating in µm
Tank	18 / 16 / 13	5 µm (single pass elements)
Injection system	12 / 10 / 8	5 µm (single pass elements)

1) Poor conditions can be caused by large flow rate fluctuations, pressure peaks, frequent cold starts, extremely high ingress of dirt or the presence of water.
2) Two or more system filters with the recommended filtration rating may be required to achieve and maintain the required target cleanliness class.
3) Valid in the average diameter range

For system cleanliness, we recommend working at one class better than the required cleanliness for the most sensitive component. Filling filtration / flushing filtration to be at least one filtration rating finer than the system filters. According to DIN 51524, a cleanliness of ISO 21 / 19 / 16 must be ensured for fresh hydraulic oil.

EN 7.603.12/12.24

Saturation point

Dissolved water

Below the saturation point

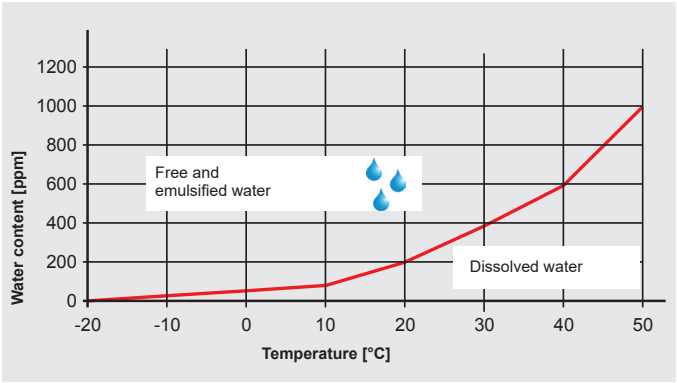
– Water is present in dissolved form – like moisture in the air.
– All water molecules are attached to polar oil components (e.g. additives, particles, oil ageing products)

Free water

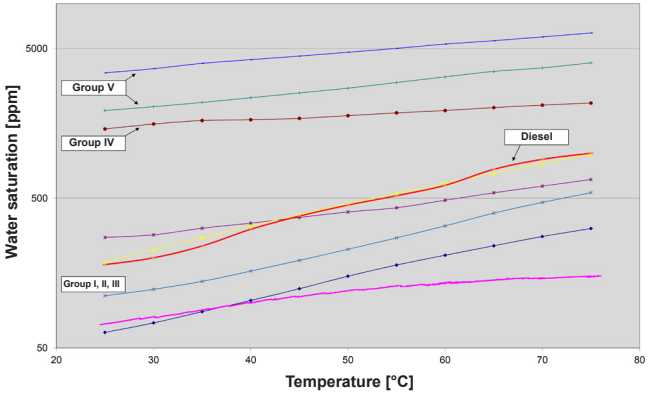
Above the saturation point

– Water is present as an emulsion (similar to mist), whereby the finest water droplets are distributed in a stable suspension in the oil. This causes the oil to become cloudy.
– Water is present in free form, which usually settles at the bottom.

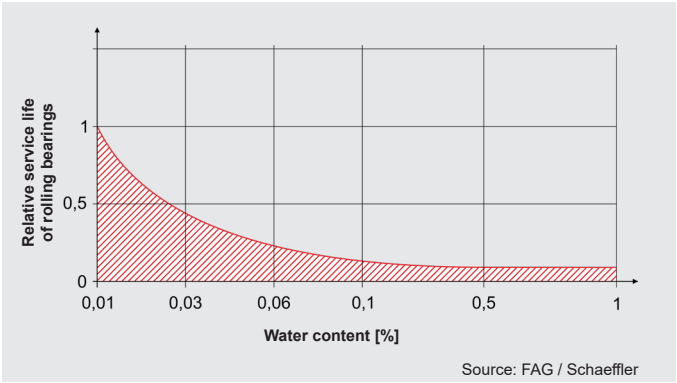
Water saturation limit in oil



Water saturation curves



Bearing service life as a function of water content



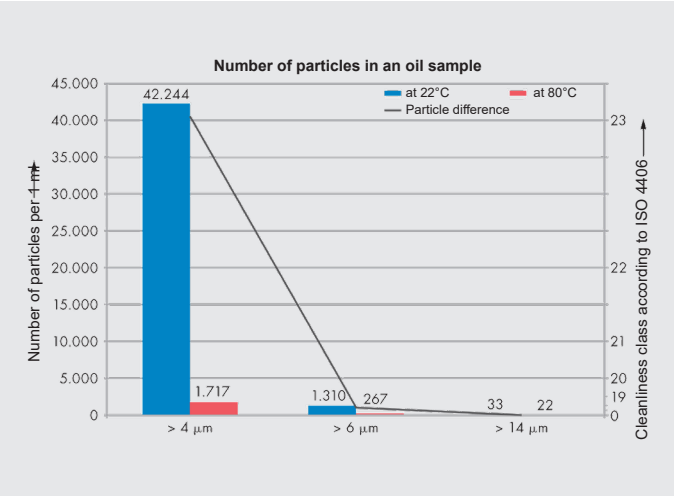
Varnish analysis method

Laboratory analyses – varnish:

– **MPC (membrane patch colorimetry)**
according to ASTM D7843-12

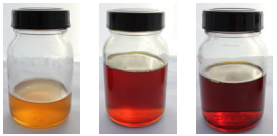
Laboratory analyses – special:

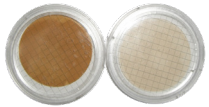
– **Particle measurement at 20°C and 80°C**
according to ISO 11500



Sample images

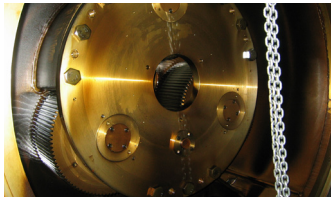

Valve piston with deposits

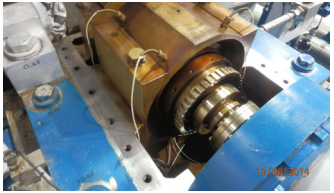

Slightly cloudy oil samples at room temperature


Filter membranes before and after varnish separation

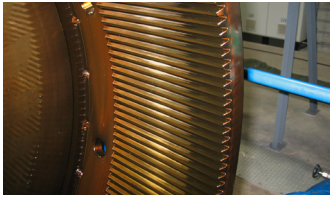
Typical images of deposits in a steam turbine

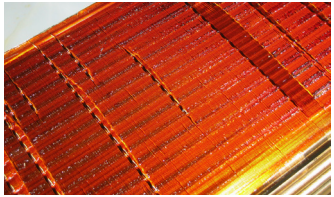

Coupling sleeve


Planetary gearbox


Radial and axial turbine bearings

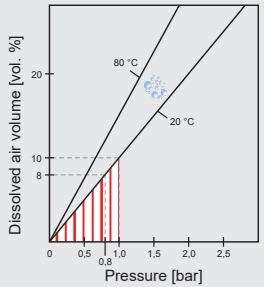

Emergency oil pump


Gear teeth


Oil cooler fins (oil side)

Solubility of air in oil

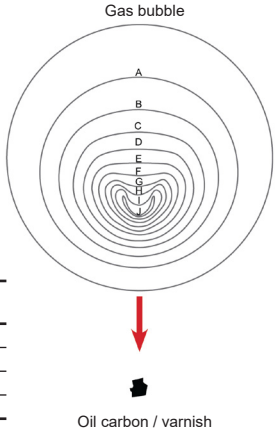
Dependence on pressure and temperature



At 20°C and 1 bar (atmospheric pressure) approx. 10 % dissolved air
→ approx. 10 litres of air in 100 litres of oil

With pressure reduction to 0.8 bar only 8 % of the air is soluble
→ 2 litres of air are released in 100 litres of oil!

Fluid ageing due to cavitation

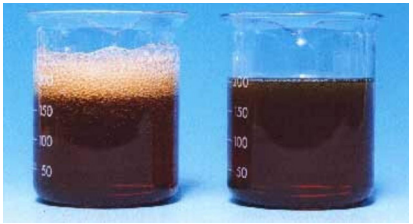


Range	Pressure	Tempera-ture
A	1 bar	38°C
F	69 bar	766°C
H	138 bar	994°C
I	207 bar	1,140°C

Air separation capacity for fresh oils

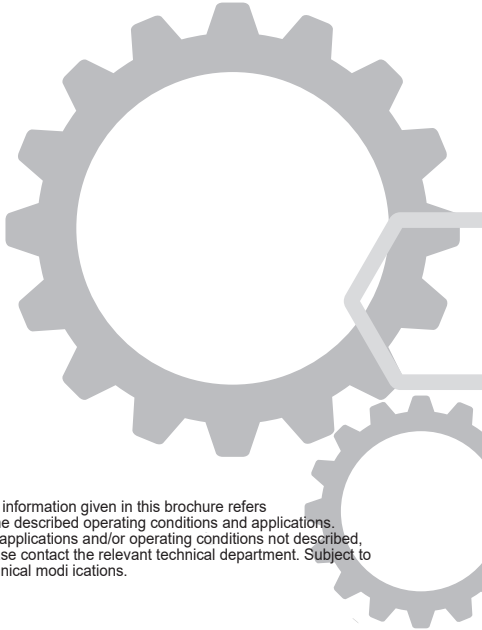
Limit values of typical standards for fresh oil						
ISO VG / type	**32**	**46**	**68**	**100**	**(150)**	**(> 320)**
Turbine oil DIN 51515, ISO 8068	5	5	6	x	x	x
Hydraulic fluid (HLP / HM) DIN 51524/2, ISO 11158	5	10	13	21	32	x

Sample images



Product portfolio

Type of contamination	Measuring devices (online / offline)	Typical separation methods / oil maintenance devices
Solid	 ContaminationSensor **CS 1000**  Metallic ContaminationSensor **MCS 1000**  ContaminationSensor Module Economy **CSM-E**  FluidControl Unit **FCU 1315**	Filtration units  MobileFiltration Unit **MFU**  OffLine Filter **OLF 5**  OffLine Filter **OLF 60**
Liquid	 AquaSensor **AS 1000 and AS 3000**  ContaminationSensor Module Economy **CSM-E**  FluidControl Unit **FCU 1315**	Vacuum drainage  FluidAqua Mobil **FAM** Coalescence  OffLine Separator **OLS** Super absorbers  MobileFiltration Unit **MFU**  LowViscosity Housing Coalescer Diesel **LVH-CD**  Aquamicron **AM**
Gel-like		Cold filtration  VarnishElimination Unit **VEU-F** Ion exchangers  Ion eXchange Unit **IXU**
Gaseous		Vacuum drying  FluidAqua Mobil **FAM**



The information given in this brochure refers to the described operating conditions and applications. For applications and/or operating conditions not described, please contact the relevant technical department. Subject to technical modi ications.

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