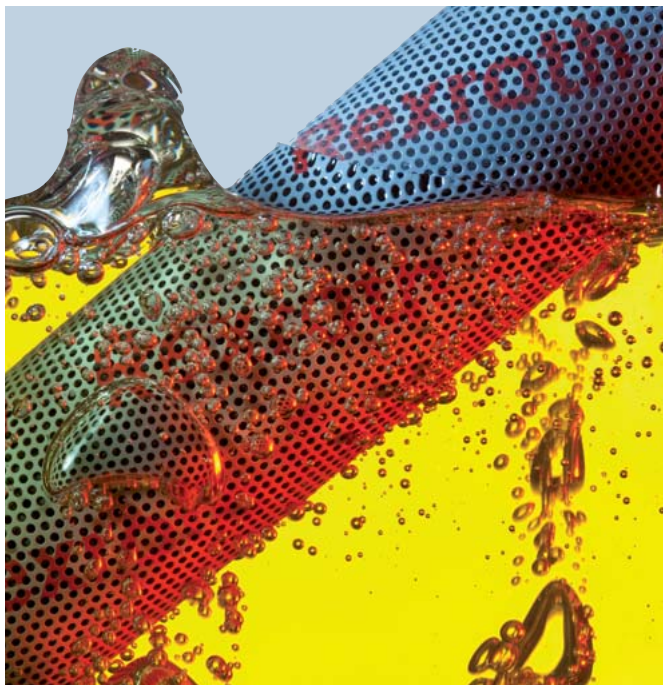


The Drive & Control Company

Rexroth
Bosch Group

Rexroth Oil Cleanliness Booklet



Introduction

Oil is the central component of any hydraulic system. If a system fails, contamination is one of the major reasons. This booklet explains the basics of contamination control and serves as a reference and information tool.



04 Need for Hydraulic Filtration

05 Sources of Problems with Fluid Systems

06 Classical Oil Analysis

07 MPC 4614 Mobile Particle Counter

08 Contamination – Types, Origin, Examples

12 Damage Caused by Contamination

13 The Objective

14 Filtration Grade – Particle Sizes

16 Achievable Oil Cleanliness in Accordance with ISO 4406

17 Overview of the Key Filter Properties

18 Fitting Tolerance of Hydraulic Components

19 Recommended Oil Cleanliness Level

20 Oil Cleanliness Codes in Accordance with ISO 4406

32 Fluid and Product Service

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Need for Hydraulic Filtration



Inspecting contamination in hydraulic systems is a major aspect when designing a filter concept.

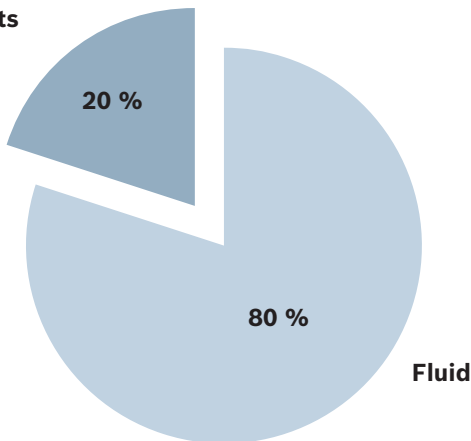


Sources of Problems in Fluid Systems

More than $\frac{3}{4}$ of all problems can be traced back to contaminated oil. Monitoring oil cleanliness is therefore the most important factor in preventing system failures.

Monitoring hardware only detects around 20 % of all unplanned downtimes.

Components

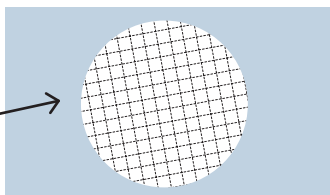
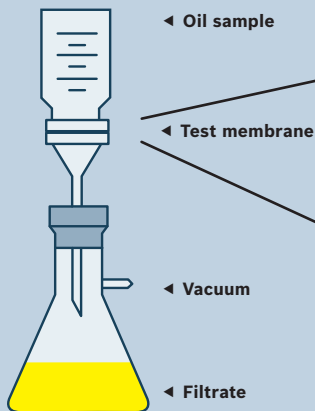


Oil Analysis

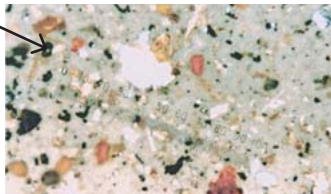
Types of inspection for oil cleanliness

- ▶ Offline examination of oil samples in the laboratory
- ▶ Microscopic particle count in accordance with ISO 4407
- ▶ Gravimetric test in accordance with ISO 4405
- ▶ Microscopic determination of the type of contamination

Vacuum filtration device:



▲ Test membrane, 1,2 μm



▲ Microscopic image, 100 x

With the new OPMII the contamination level of fluids in hydraulic systems can be easily monitored and digitally recorded.



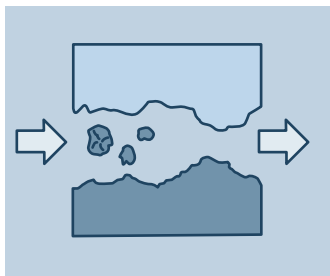
Advantages resulting from special product features

- ▶ Precise: display of the purity class is in conformity with ISO 4406:99 or SAE AS4059E.
- ▶ Easy: to operate and configure via the display
- ▶ Recording: with integrated data memory
- ▶ Clear layout: display in 4 size classes
- ▶ Flexible: space-saving dimensions
- ▶ Safe: an alarm is emitted if the limit value is exceeded

Key technical data

- ▶ Permissible working pressure: 6092 psi
- ▶ Permissible flow rate: 0,013 to 0,105 gpm
- ▶ Calibrated measuring range: 10 ... 22 in ordinal numbers
- ▶ Measuring accuracy: + - ordinal number
- ▶ Interfaces: RS232, CANopen

Types of Contamination



1. Solid particles (abrasion and dirt)

Consequences:

- ▶ Initial damage through “scoring”
- ▶ Impact on control and regulation properties
- ▶ Component wear
- ▶ Component failure
- ▶ Reduction in machine availability

Measures: Filtration

2. Liquid contamination (usually water, free and in solution)

Consequences:

- ▶ Corrosion, wear
- ▶ Impairment of viscosity
- ▶ Chem. reaction with the fluid
- ▶ Impact on lubricating properties
- ▶ Ageing (oxidation) of oil
- ▶ Poor filterability
- ▶ Reduction in filter service intervals
- ▶ Reduction in machine availability

Measures:

- ▶ Breather filters with AS filter material
- ▶ Water absorbing filter elements (free)
- ▶ Vacuum dehydrator (water in solution)

3. Gaseous contamination (air)

Consequences:

- ▶ Foam formation in the oil
- ▶ Inaccurate valve response
- ▶ Loss of energy
- ▶ Pump damage
- ▶ Chem. reaction with the fluid
- ▶ Oxidation
- ▶ Reduction in machine availability

Measures:

- ▶ Bleed system
- ▶ Seal pumps
- ▶ Use a vacuum dehydrator

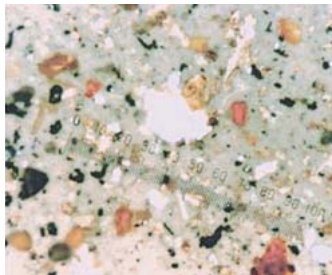
Sources of Contamination

1. Built-in contamination

- ▶ Foundry sand, dust
- ▶ Manufacturing residue:
 - Welding residue
 - Metal swarf
 - Blasting material, lacquer/paint particles
 - Preservation material
- ▶ Residue from cleaning agents (textile fibers)

2. External contamination

- ▶ Dirt from the ambient air, introduced via
 - Plunger rods
 - Labyrinth seals
 - Aeration
- ▶ Contamination caused by adding oil



3. Self-generated contamination

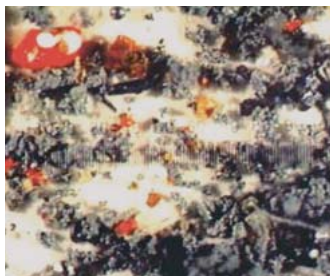
- ▶ Metallic wear caused by abrasion and erosion
- ▶ Seal abrasion
- ▶ Chemical corrosion
- ▶ Oil ageing products
- ▶ Oxidation residue
- ▶ Oil-insoluble substances caused by mixing oil

Examples of Residual Dirt

Built-in contamination

Residue from a return line filter
(mobile hydraulic systems)

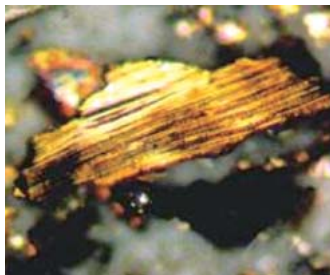
- ▶ Welding residue
- ▶ Metal swarf
- ▶ Paint residue
- ▶ Resin



Self-generated contamination (wear)

Residue from a high-pressure
filter in a hydraulic system within
a stainless steel forging press

- ▶ Coarse brass and steel
abrasion particles
- ▶ Severe sliding wear (grooves
and stress marks)



Damage Caused by Contamination

Material removal (erosion)

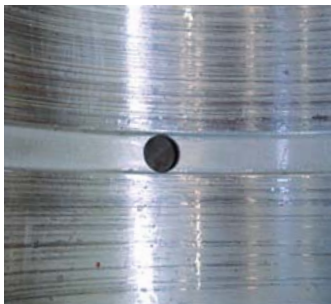
caused by a high flow rate along edges combined with a high number of ingressed dirt particles with high speed in the flow.



Grooving (abrasion)

caused by hard, abrasive particles that are roughly the same size as the clearance of the components.

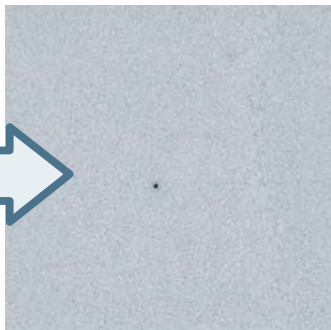
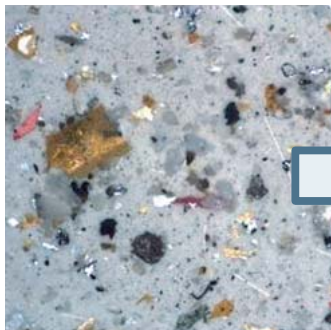
Consequence: Reduction in performance due to leaking oil.



The Approach

Prevent with Rexroth filter technology.

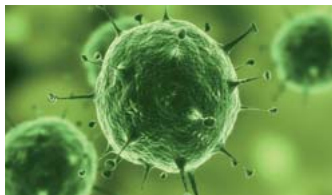
- ▶ Optimum oil cleanliness
- ▶ Major contribution towards machine availability
- ▶ Reliable component protection
- ▶ High degree of customer satisfaction



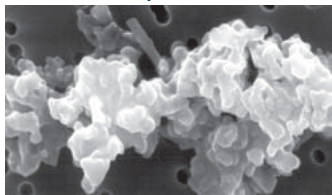
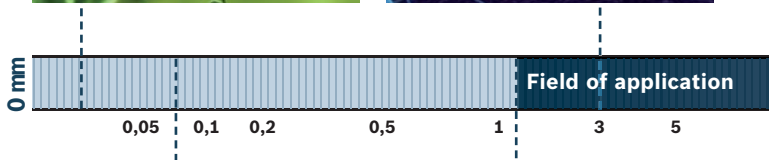
- ▶ High degree of oil contamination
- ▶ ISO 22/20/18
- ▶ Achievable oil cleanliness using fine filter elements
- ▶ ISO 12/10/8

Filtration Grade – Particle Sizes

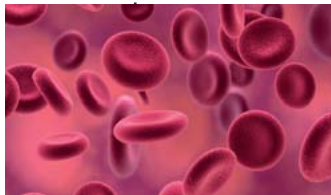
▼ Viruses 0,003 – 0,05 μm



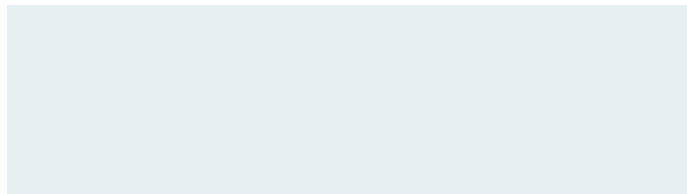
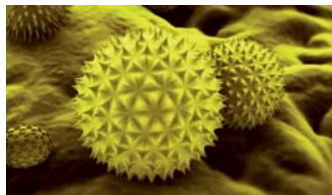
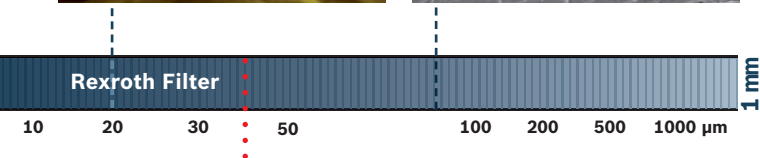
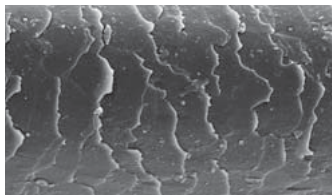
▼ Bacteria 0,3 – 20 μm



▲ Tobacco smoke 0,01 – 1 μm



▲ Blood cells 0,5 – 1,5 μm

▼ Pollen ~ 20 μm ▼ Human hair ~ 70 μm ▲ Visibility limit = 40 μm

Particle sizes are measured in units called “micrometers”.

A micrometer is one millionth of a meter.

The visibility limit of the human eye is approx. 40 μm . This means that particles that are the most hazardous to a hydraulic system cannot be detected with the naked eye.

Achievable Oil Cleanliness in Accordance with ISO 4406

Filter material with PURE POWER (PWR)

PWR20	19/16/12 - 22/17/14
PWR10	17/14/10 - 21/16/13
PWR6	15/12/10 - 19/14/11
PWR3	13/10/8 - 17/13/10
PWR1	10/6/4 - 14/8/6

Achievable oil cleanliness codes can not be guaranteed, as they depend on various application parameters such as ingress rate of contamination, particle size distribution, size, shape and material of particles. Other operating conditions like flow and pressure pulsation will also effect oil cleanliness. Finally oil cleanliness depends on specified filter service intervals. Indicated

oil cleanliness codes in the above table are based on experience and are valid for operating fluids except non-flammable fluids. For these fluids, especially HFA and HFC types, one ISO code higher may appear. Validation of oil cleanliness codes for these fluids is only acceptable for microscopic particle counting.

Overview of the most important Filter Characteristics

β_x
 α
 Δp

Filtration grade

- ▶ Nominal (from manufacturer)
- ▶ “Absolute” in accordance with ISO 16889
- ▶ Mesh width for wire fabric

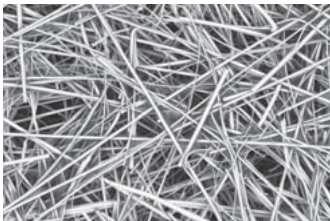
Dirt absorption capacity

- ▶ In accordance with ISO 16889
- ▶ ISOMTD test dust

Differential pressure

- ▶ In accordance with ISO 3968
- ▶ In relation to 30 cSt/25 μm

All three properties are mutually interdependent. Rexroth filter elements are characterized by an optimum ratio for these properties, ensuring the best possible filtering action with maximum dirt absorption and minimum Δp .



Fitting Tolerance of Hydraulic Components

The tolerated particle size in hydraulic fluid results come from the clearance between the moving parts of the component.

Gear pump Gear pump, Side plate Gear housing	0,5 - 5 µm 0,5 - 5 µm
Vane pump Vane tip Vane surfaces	0,5 - 5 µm 5 - 13 µm
Piston pump Piston bore Valve plate cylinder	5 - 40 µm 1,5 - 10 µm
Servo valve Control piston Baffle plate	18 - 63 µm 2,5 - 8 µm
Control valve Control piston Cone valve	2,5 - 23 µm 13 - 40 µm

In combination with the system pressure as well as the general sensitivity of a component, the so called fluid cleanliness is derived, and stated in the data sheet of the respective component.

High class filter elements are able to capture even smaller particles than indicated on the grade of filtration.

The indicated grades of filtration are recommendations based on a great deal of information gathered from many different systems over many years.

Besides contamination of hard particles, the users have to take into account other influences such as environmental conditions and also production processes. Counted among these are e.g. the influence of water and or air in the oil.

Recommended Oil Cleanliness Level

Application	Oil cleanliness required in accordance with ISO 4406	Recommended filter material/ filtration grade
Systems with extremely high dirt sensitivity and very high availability requirements	≤ 16/12/9	PWR1/1 μm
Systems with high dirt sensitivity and high availability requirements, such as servo valve technology	≤ 18/13/10	PWR3/3 μm
Systems with proportional valves and pressures > 160 bar	≤ 18/14/11	PWR6/6 μm
Vane pumps, piston pumps, piston engines	≤ 19/16/13	PWR10/10 μm
Modern industrial hydraulic systems, directional valves, pressure valves	≤ 20/16/13	PWR10/10 μm
Industrial hydraulic systems with large tolerances and low dirt sensitivity	≤ 21/17/14	PWR20/20 μm

Oil Cleanliness Codes in Accordance with ISO 4406 and Examples of Contamination

Number of particles (per 100 ml)		ISO- Code
from	to	
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

Classification of all particles

$\geq 4 \mu\text{m(c)}$, $\geq 6 \mu\text{m(c)}$ and
 $\geq 14 \mu\text{m(c)}$

Example from ISO 18/16/11:

190.000 particles $\geq 4 \mu\text{m(c)}/100 \text{ ml}$
 58.600 particles $\geq 6 \mu\text{m(c)}/100 \text{ ml}$
 1.525 particles $\geq 14 \mu\text{m(c)}/100 \text{ ml}$

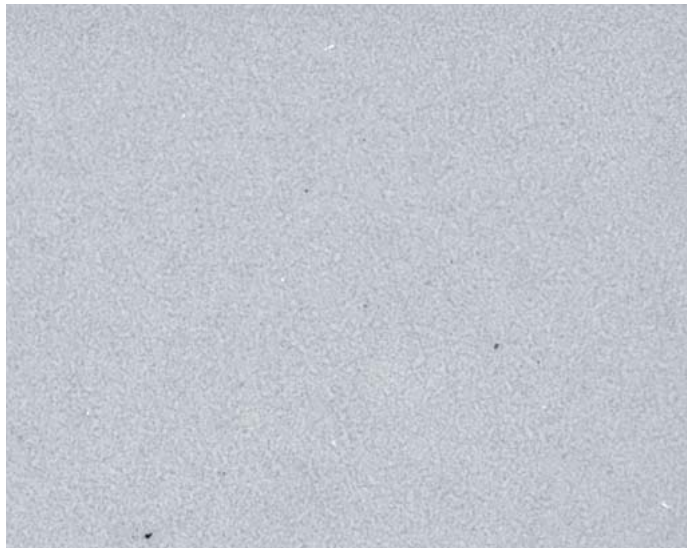
ISO 4406 counts particles accumulatively, i.e. all particles that are larger than or equal to $4 \mu\text{m}$. In contradiction to this, NAS 1638 counts the particles in differential size classes, i.e. all particles within the range of $5 - 15 \mu\text{m}$, $15 - 25 \mu\text{m}$, etc.

NAS 1638 became INVALID on 05/30/2001!

The replacement standard SAE AS 4059 is a national standard intended for the US aviation industry only. It is therefore no longer permitted to specify contamination classes in accordance with NAS. Specifying contamination in accordance with ISO 4406 on the other hand is considered to be state-of-the-art.

ISO 10/7/5

(NAS 1638: class 1)

200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
500 to 1.000	64 to 130	16 to 32

ISO 12/11/6

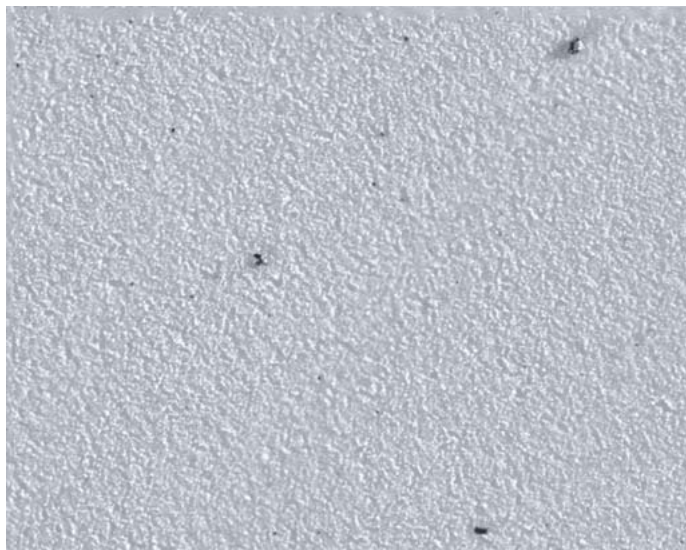
(NAS 1638: class 2)

200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
2.000 to 4.000	1.000 to 2.000	32 to 64

ISO 14/13/9

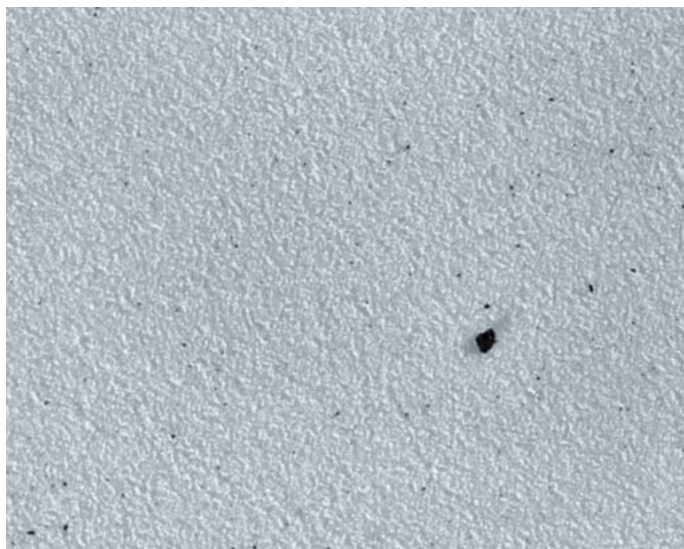
(NAS 1638: class 3)

200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
8.000 to 16.000	4.000 to 8.000	250 to 500

ISO 16/14/10

(NAS 1638: class 5)


200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
32.000 to 64.000	8.000 to 16.000	500 to 1.000

ISO 17/15/13

(NAS 1638: class 6)

200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
64.000 to 130.000	16.000 to 32.000	4.000 to 8.000

ISO 18/16/13

(NAS 1638: class 7)

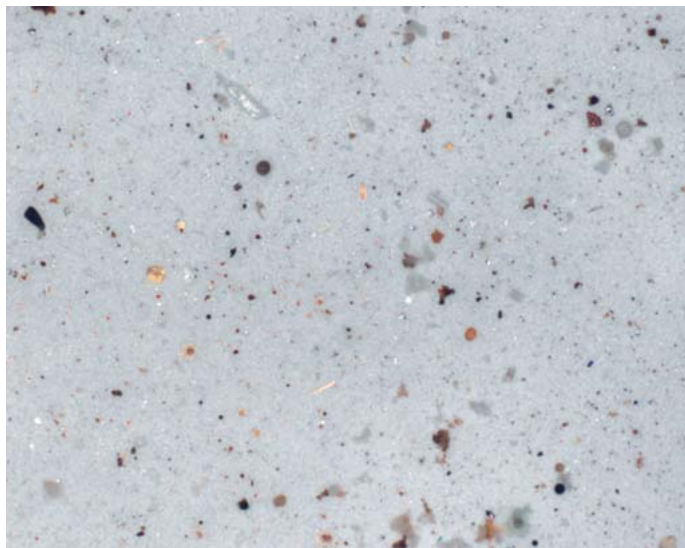


200 μm

Particle size		
≥ 4 μm(c)	≥ 6 μm(c)	≥ 14 μm(c)
Particle count		
130.000 to 250.000	32.000 to 64.000	4.000 to 8.000

ISO 19/17/14

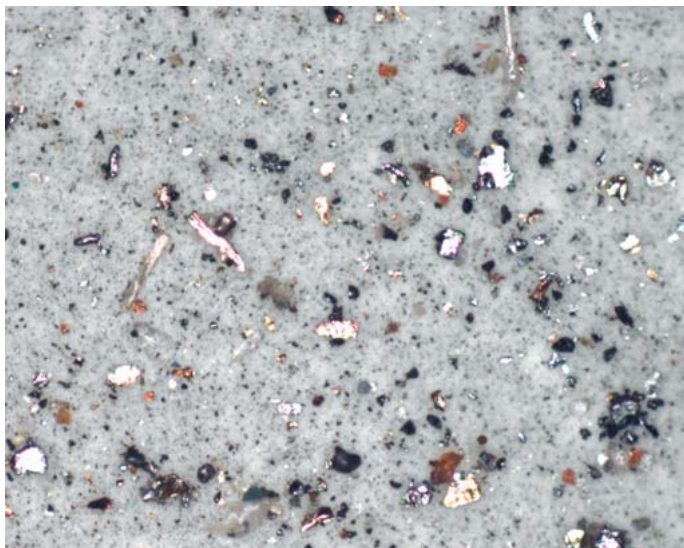
(NAS 1638: class 8)

200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
250.000 to 500.000	64.000 to 130.000	8.000 to 16.000

ISO 22/19/17

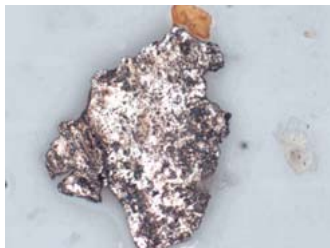
(NAS 1638: class 10)



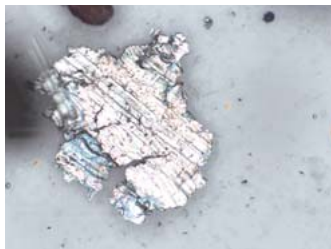
200 μm

Particle size		
$\geq 4 \mu\text{m(c)}$	$\geq 6 \mu\text{m(c)}$	$\geq 14 \mu\text{m(c)}$
Particle count		
2.000.000 to 4.000.000	250.000 to 500.000	64.000 to 130.000

Fatigue wear, 500 x ►



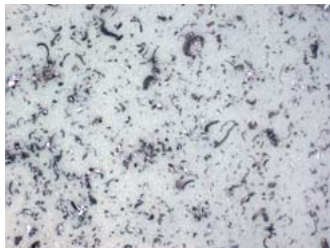
50 µm



50 µm

◄ **Sliding wear, 500 x**

Cutting wear, 100 x ►



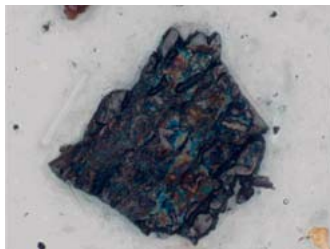
200 µm



◀ **Cutting wear, 500 x**

50 μ m

Dark, shiny metal, 500 x ▶



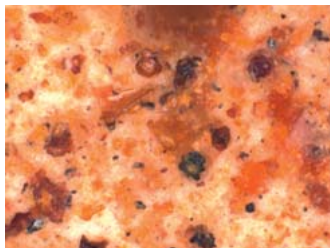
50 μ m



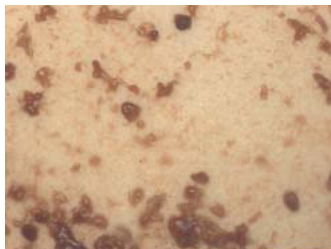
◀ **Copper particles, 500 x**

50 μ m

Red iron oxide, 500 x ►



50 µm



100 µm

◄ **Greasy/resinous residue, 500 x**

Seal abrasion, 500 x ►



50 µm

Fluid and Product Service

- ▶ Oil analysis – particles, water content, residual additives
- ▶ Filter element analysis
- ▶ System flushing and decontamination
- ▶ Advice on oil cleanliness and oil maintenance



Extract from the Product Range





Online Particle Monitor OPM II

- ▶ Light extinction method
- ▶ Measurement: oil cleanliness
ISO 4406/ SAE AS 4059E
4; 6; 14; 21 $\mu\text{m} \pm 1$ classes
- ▶ Data memory
- ▶ Programmable alarm contact

Data sheet: 51460



Online Water-Content Measuring Device

- ▶ Application: Online determination
of water activity in hydraulic
systems and lubricating oil
- ▶ Measurement range: 0 – 100 % of
the saturation of water in oil
- ▶ With optional data memory,
network or alarm module

Data sheet: 51438

51439



VacuClean® Oil Purification VCM 50-2X

- ▶ Operating data: End vacuum up to 50 mbar
- ▶ Oil flow rate: 5 – 50 l/min

Data sheet: 51435



Offline Filter Units (portable, 2- and 4-wheel design)

- ▶ Volume flow: 10, 15, 30, 35, 50, 80 l/min.
- ▶ Filter type: 40 LE 0018, 7 SL 45, 7 SL 130, 40 FLE 0045, 40 FLE 0095, 40 FLE 0120

Data sheet: 51433B
91B_04
51431-B
51433



Filter for Mobile Hydraulics

- ▶ Type 7SL 30 to 260
- ▶ Type 7SLS 90 to 260
- ▶ Type 50SL 30 to 80D

Data sheet: 51426



Filling and Breather Filter

- ▶ Typ FEF0
- ▶ Typ FEF1

Data sheet: 51413



Filter Elements with PURE POWER (PWR)

- ▶ Typ 1., Typ 2.
- ▶ Size according to DIN 24550
0040 – 1000
Size 0003 – 0270

Data sheet: 51420



Filter Elements with PURE POWER (PWR)

- ▶ Typ 9., Typ 10., Typ 16., Typ 17.,
Typ 18.
- ▶ Replaceable filter elements for
Hydac, Pall, Eaton and Mahle filter
housings

Data sheet: 51457
51464
51465
51466



Filter Elements

- ▶ Typ 65.
- ▶ Replaceable two stage filter elements for Hydac filter housings (Windmills)

Data sheet: 51461



Filter Elements

- ▶ Typ 73.
- ▶ Two stage filter elements for Rexroth filter housings (Windmills)

Data sheet: 51458



Inline Filter

Data sheet:

- 51401 Type 40 FLEN 0160 to 1000
- 51402 Type 100 FLEN 0160 to 0630
- 51403 Type 16 FE 2500 to 7500
- 51421 Type 245 LEN 0040 to 0400
- 51422 Type 350 LEN 0040 to 1000
- 51423 Type 445 LEN 0040 to 1000
- 51447 Type 50 LEN 0040 to 0400
- 51448 Type 110 LEN 0040 to 0400



Tank Mounted Filter

Data sheet:

- 51424 Type 10 TEN 0040 to 1000
- 51424 Type 10 TE 2000 to 2500



Tank Mounted Return Line Filter

- Typ 25TE 0101 to 1051
(according to Rexroth
standard)

Data sheet: 51472



Manifold Mounted Filter

Data sheet:

- 51417 Type 450 PBFN 0040 to 1000
- 51418 Type 245 PSFN 0040 to 0400
- 51419 Type 350 PSFN 0040 to 1000
- 51427 Type 320 PZR 025, 075, 125



Duplex Filter

Data sheet:

- 51456 Type 50 LDN 0040 to 0400
- 51446 Type 150 LDN 0040 to 0400
- 51408 Type 40 FLDN 0160 to 1001
- 51409 Type 100 FLDN 0160 to 1000
- 51410 Type 16 FD 2500 to 7500
- 51429 Type 400 LDN 0040 to 1000



Duplex Filter

- Type 63 FLDK(N) 0063 bis 0250

Data sheet: 51445



Duplex Filter

- Typ 16FD 2500 to 7500

Data sheet: 51410

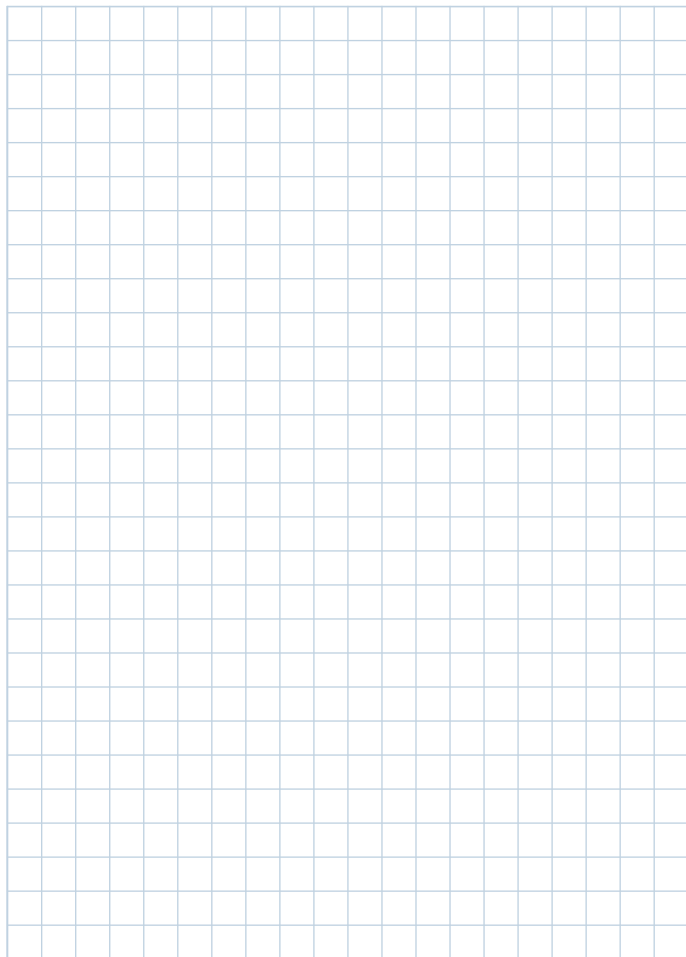


Filter for Process Engineering

- Type 16 FKE 25/400 to 150/2500
- Type 16 FKD 25/400 to 150/2500

Design coated in steel
and stainless steel

Data sheet: 58B



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MI • IN • IL • OH • ON, CAN

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