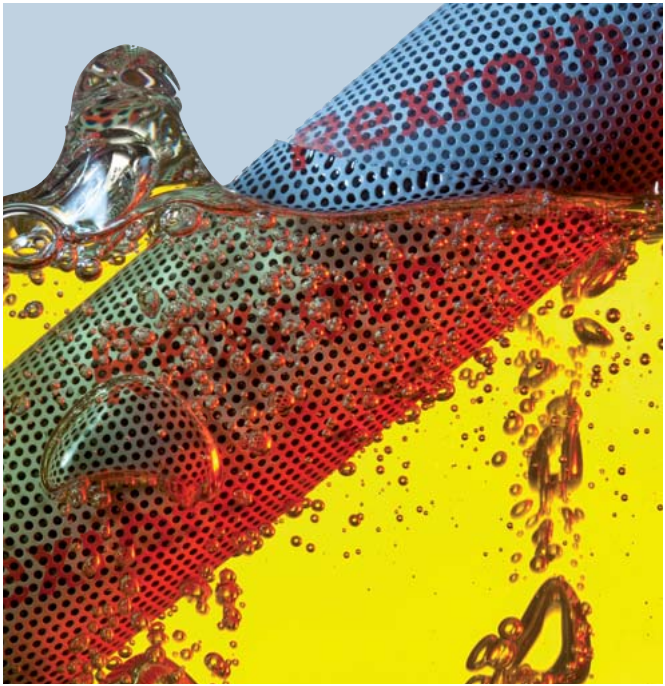
The Drive & Control Company

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.

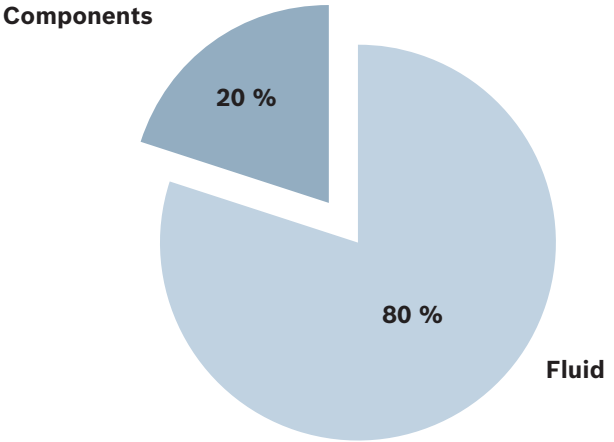
# Need for Hydraulic Filtration

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

# Sources of Problems in Fluid Systems

More than ¾ of all problems can be traced back to contaminated oil. Monitoring oil cleanliness is therefore the most important factor in preventing system failures.

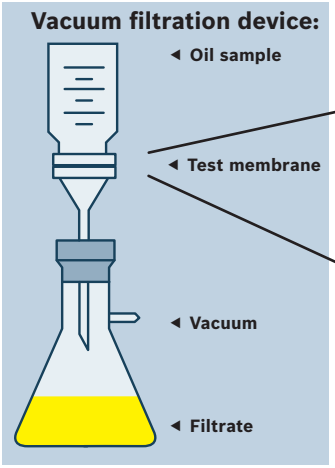
Monitoring hardware only detects around 20 % of all unplanned downtimes.

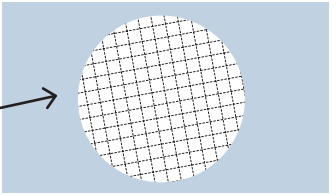


# Oil Analysis

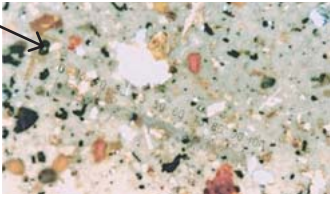
## Types of inspection for oil cleanliness

- 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



▲ 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.

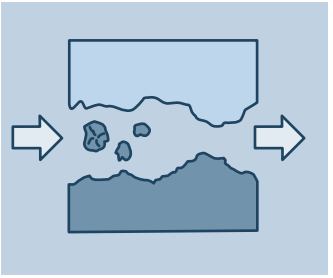

**Advantages resulting from special product features**

- 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

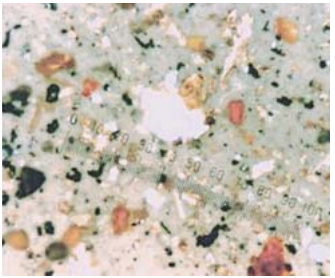
# Sources of Contamination

### 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



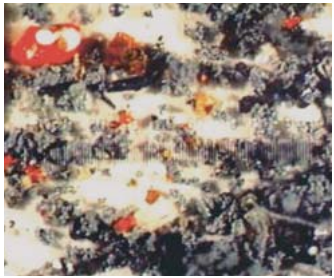
### 3. Self-generated contamination

- 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



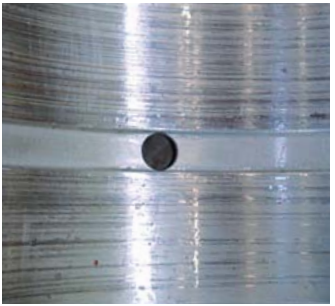
**Self-generated contamination (wear)**
Residue from a high-pressure filter in a hydraulic system within a stainless steel forging press

- 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.

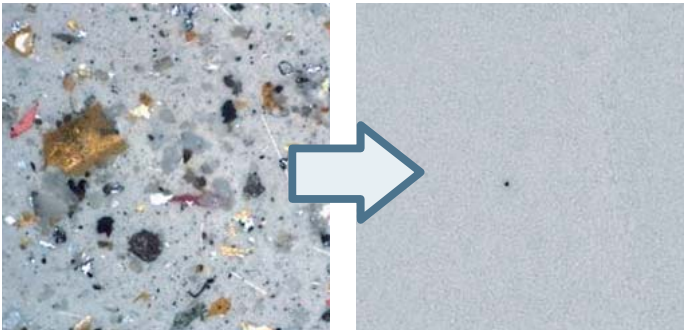
**Grooving (abrasion)**
caused by hard, abrasive particles that are roughly the same size as the clearance of the components.
Consequence: Reduction in performance due to leaking oil.



# The Approach

**Prevent with Rexroth filter technology.**

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

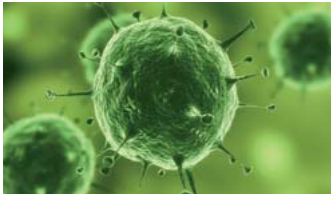


- High degree of oil contamination
- ISO 22/20/18

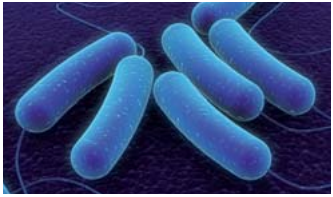
- Achievable oil cleanliness using fine filter elements
- ISO 12/10/8

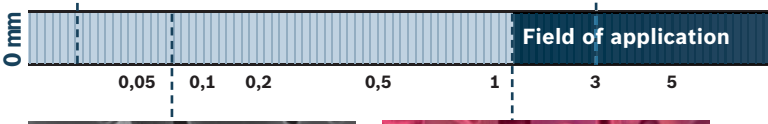
# Filtration Grade – Particle Sizes

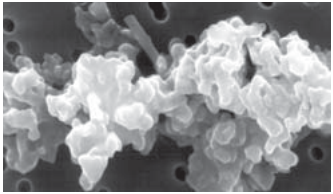
▼ **Viruses 0,003 – 0,05 µm**



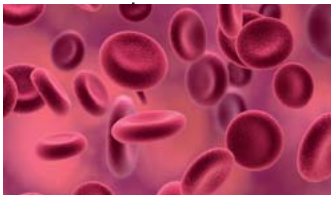
▼ **Bacteria 0,3 – 20 µm**





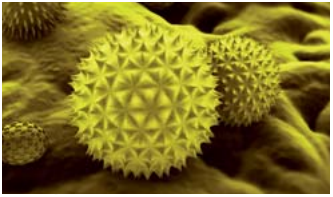



▲ **Tobacco smoke 0,01 – 1 µm**

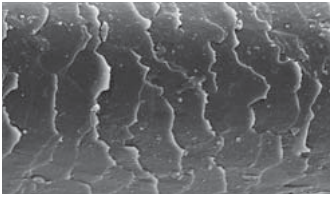


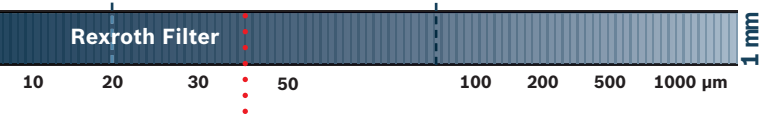
▲ **Blood cells 0,5 – 1,5 µm**

▼ **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 guaruanteed, as they depend on various application parameters such as ingression 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 vaild 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

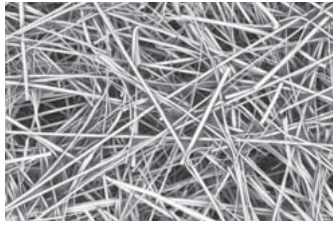
$$\beta_x$$
$$\alpha$$
$$\Delta p$$

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

▲ **Extract from CETOP RP 92H**

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 |

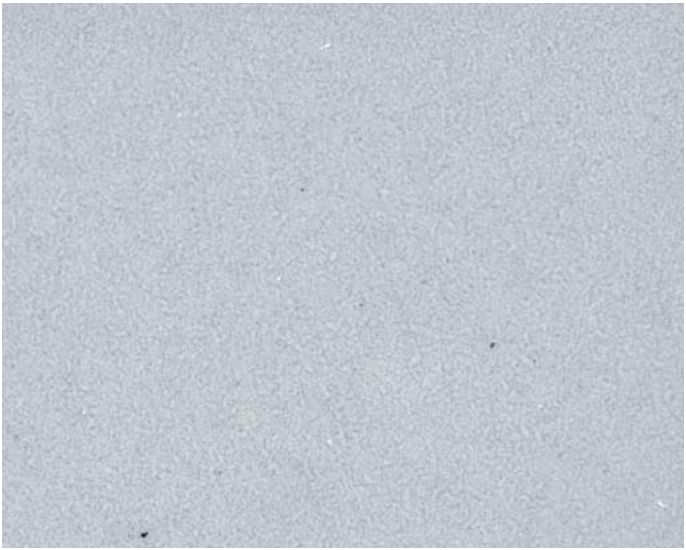
**Classification of all particles**
≥ 4 µm(c), ≥ 6 µm(c) and
≥ 14 µm(c)

**Example from ISO 18/16/11:**
190.000 particles ≥ 4 µm(c)/100 ml
58.600 particles ≥ 6 µm(c)/100 ml
1.525 particles ≥ 14 µm(c)/100 ml

ISO 4406 counts particles accumulatively, i.e. all particles that are larger than or equal to 4 µm. In contradiction to this, NAS 1638 counts the particles in differential size classes, i.e. all particles within the range of 5 – 15 µm, 15 – 25 µm, 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)




| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 500 to 1.000 | 64 to 130 | 16 to 32 |

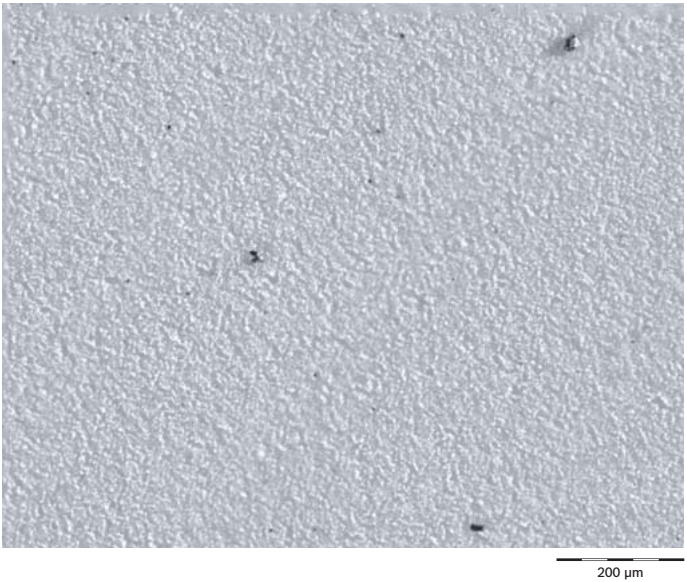
# ISO 12/11/6

(NAS 1638: class 2)


| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 2.000 to 4.000 | 1.000 to 2.000 | 32 to 64 |

# ISO 14/13/9

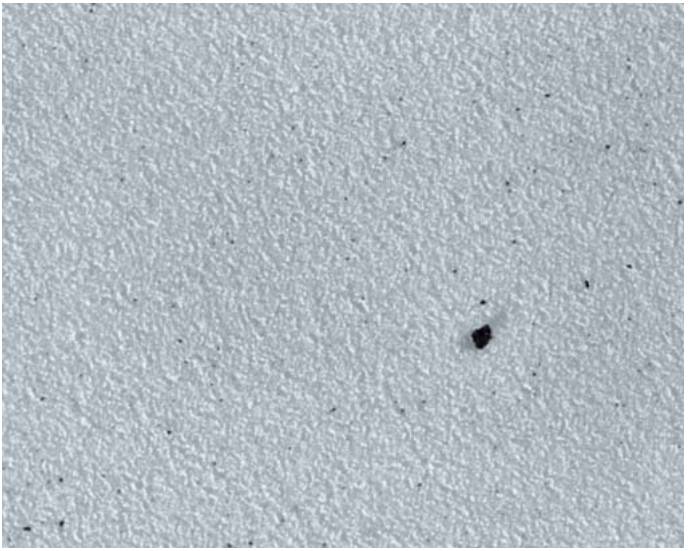
(NAS 1638: class 3)




| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 8.000 to 16.000 | 4.000 to 8.000 | 250 to 500 |

# ISO 16/14/10

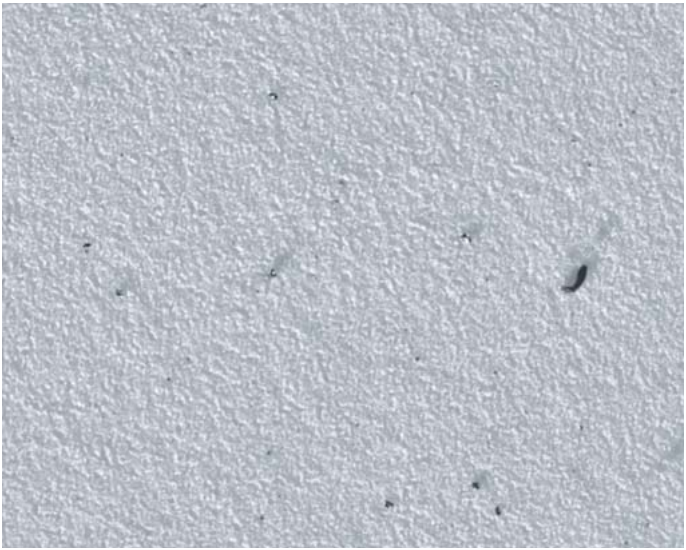
(NAS 1638: class 5)




| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 32.000 to 64.000 | 8.000 to 16.000 | 500 to 1.000 |

# ISO 17/15/13

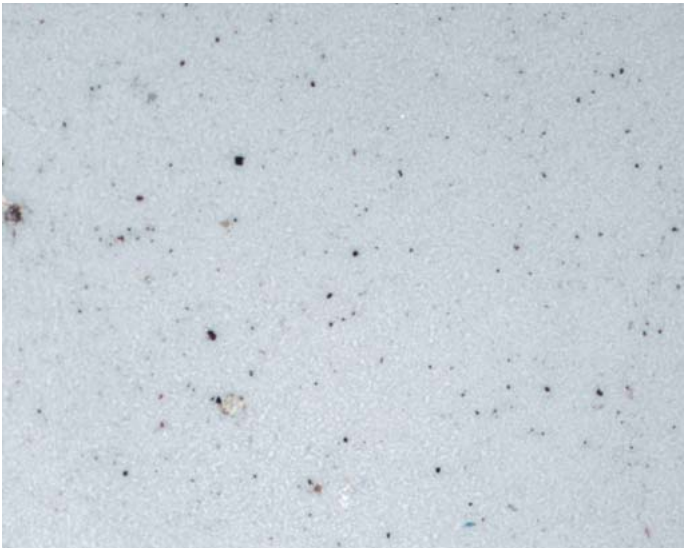
(NAS 1638: class 6)




| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 64.000 to 130.000 | 16.000 to 32.000 | 4.000 to 8.000 |

# ISO 18/16/13

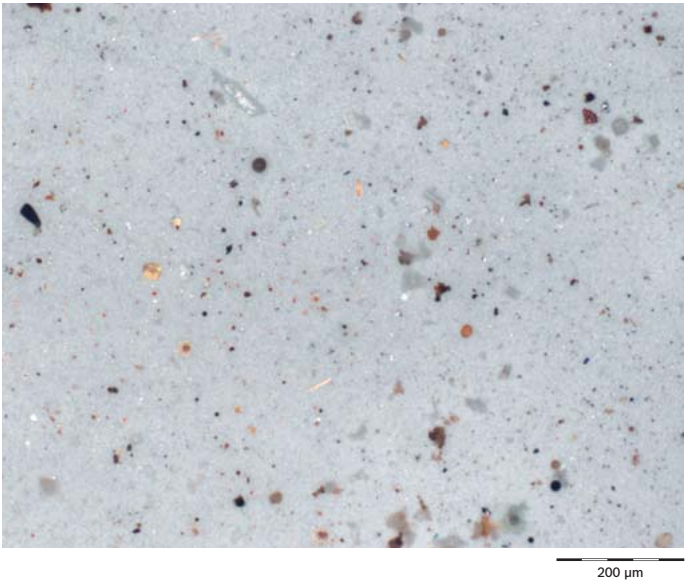
(NAS 1638: class 7)




| **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

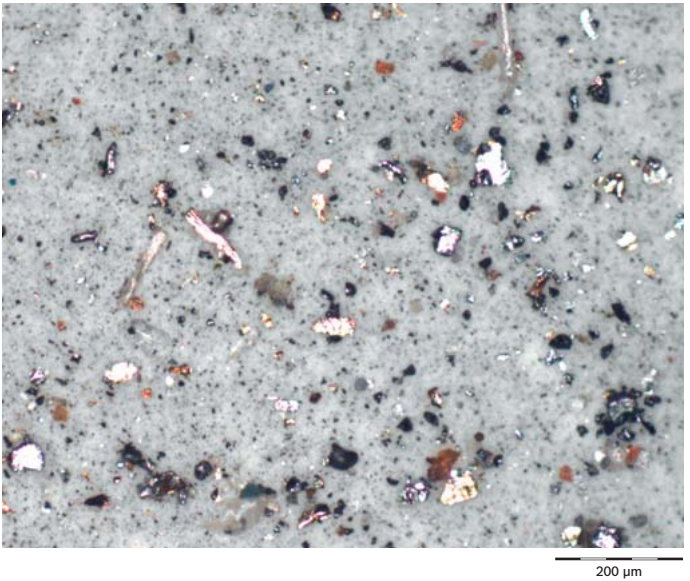
(NAS 1638: class 8)




| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 250.000 to 500.000 | 64.000 to 130.000 | 8.000 to 16.000 |

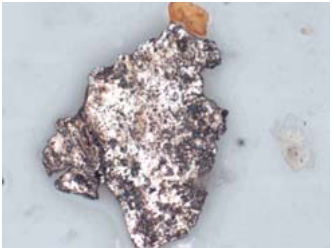
# ISO 22/19/17

(NAS 1638: class 10)

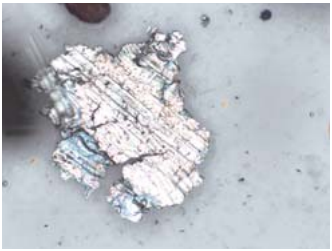



| **Particle size** | | |
|---|---|---|
| ≥ 4 µm(c) | ≥ 6 µm(c) | ≥ 14 µm(c) |
| **Particle count** | | |
| 2.000.000 to 4.000.000 | 250.000 to 500.000 | 64.000 to 130.000 |

**Fatigue wear, 500 x ▶**



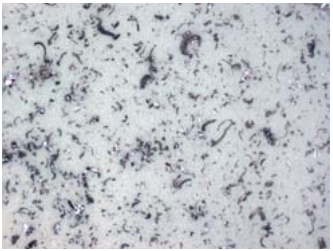
50 µm



50 µm

**◀ Sliding wear, 500 x**

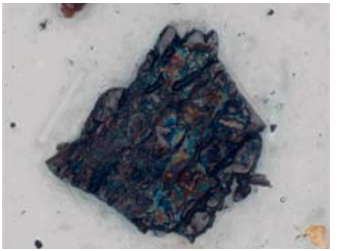
**Cutting wear, 100 x ▶**



200 µm


◀ **Cutting wear, 500 x**

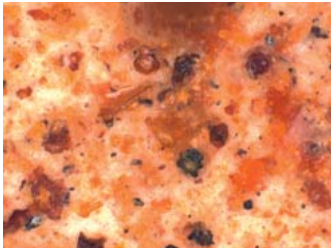
**Dark, shiny metal, 500 x** ▶



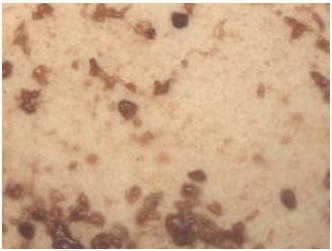


◀ **Copper particles, 500 x**

**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 µm ± 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

The Drive & Control Company

Rexroth
Bosch Group

Bosch Rexroth AG
Hardtwaldstraße 43
68775 Ketsch
Germany
Phone +49 6202 603-0
Fax +49 6202 603-199
info-ket@boschrexroth.de
www.boschrexroth.com

You can find your local contacts at:
**www.boschrexroth.com/adressen**





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