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 |
| 33 Fluidmanagement Products |
| 41 Notes |
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.

Components

- Fluid: 80 %
- Components: 20 %
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:

- Oil sample
- Test membrane, 1.2 µm
- Vacuum
- Filtrate

Microscopic image, 100 x
Mobile Particle Counter for Conducting Online Measurements of the Oil Cleanliness Class

- Light extinction principle
- Laser sensor
- Robust and reliable device with all basic functions
- Integrated battery pack and memory
- Oil cleanliness classes in accordance with ISO 4406: 4 µm(c), 6 µm(c), 14 µm(c)
- Comprehensive range of accessories, e.g. printer, tank pump, external memory card
- Very easy to use
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 Objective | Oil Cleanliness Booklet

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
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 codes cannot be guaranteed, as they depend on various application parameters such as ingestion rate of contamination, particle size distribution, size, shape and material of particles. Other operating conditions like flow and pressure pulsation will also affect 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 in table 11 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.

<table>
<thead>
<tr>
<th>HydroClean XL filter material</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H20XL</strong></td>
<td>19/16/12 - 22/17/14</td>
</tr>
<tr>
<td><strong>H10XL</strong></td>
<td>17/14/10 - 21/16/13</td>
</tr>
<tr>
<td><strong>H6XL</strong></td>
<td>15/12/10 - 19/14/11</td>
</tr>
<tr>
<td><strong>H3XL</strong></td>
<td>13/10/8 - 17/13/10</td>
</tr>
<tr>
<td><strong>H1XL</strong></td>
<td>10/6/4 - 14/8/6</td>
</tr>
</tbody>
</table>
Overview of the most important filter characteristics

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Fitting Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gear pump</td>
<td>0.5 - 5 µm</td>
</tr>
<tr>
<td>Gear pump, Side plate, Gear housing</td>
<td>0.5 - 5 µm</td>
</tr>
<tr>
<td>Vane pump</td>
<td>0.5 - 5 µm, 5 - 13 µm</td>
</tr>
<tr>
<td>Vane tip, Vane surfaces</td>
<td>5 - 13 µm</td>
</tr>
<tr>
<td>Piston pump</td>
<td>5 - 40 µm, 1.5 - 10 µm</td>
</tr>
<tr>
<td>Piston bore, Valve plate cylinder</td>
<td>5 - 40 µm</td>
</tr>
<tr>
<td>Servo valve</td>
<td>18 - 63 µm, 2.5 - 8 µm</td>
</tr>
<tr>
<td>Control piston, Baffle plate</td>
<td>18 - 63 µm</td>
</tr>
<tr>
<td>Control valve</td>
<td>2.5 - 23 µm, 13 - 40 µm</td>
</tr>
<tr>
<td>Cone valve</td>
<td>2.5 - 23 µm</td>
</tr>
</tbody>
</table>

Examinations show that even particles with sizes that are $\frac{1}{3} \times$ the clearance width can lead to the clearance becoming blocked. The filtration grade of the system filters should therefore be selected in such a way as to ensure the absolute filtration grade is smaller than or equal to $\frac{1}{3}$ of the smallest clearance width in the system.

Filtration grade $\leq \frac{1}{3} \times$ smallest clearance
## Recommended Oil cleanliness level

<table>
<thead>
<tr>
<th>Application</th>
<th>Oil cleanliness required in accordance with ISO 4406</th>
<th>Recommended filter material/ filtration grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems with extremely high dirt sensitivity and very high availability requirements</td>
<td>≤ 16/12/9</td>
<td>H1XL/1 µm</td>
</tr>
<tr>
<td>Systems with high dirt sensitivity and high availability requirements, such as servo valve technology</td>
<td>≤ 18/13/10</td>
<td>H3XL/3 µm</td>
</tr>
<tr>
<td>Systems with proportional valves and pressures &gt; 160 bar</td>
<td>≤ 18/16/13</td>
<td>H6XL/6 µm</td>
</tr>
<tr>
<td>Vane pumps, piston pumps, piston engines</td>
<td>≤ 19/14/11</td>
<td>H10XL/10 µm</td>
</tr>
<tr>
<td>Modern industrial hydraulic systems, directional valves, pressure valves</td>
<td>≤ 20/16/13</td>
<td>H10XL/10 µm</td>
</tr>
<tr>
<td>Industrial hydraulic systems with large tolerances and low dirt sensitivity</td>
<td>≤ 21/17/14</td>
<td>H20XL/20 µm</td>
</tr>
</tbody>
</table>
### Oil Cleanliness Codes in Accordance with ISO 4406 and Examples of Contamination

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.

#### 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

<table>
<thead>
<tr>
<th>Number of particles (per 100 ml)</th>
<th>ISO-Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>from to</td>
<td></td>
</tr>
<tr>
<td>1.000.000 2.000.000</td>
<td>21</td>
</tr>
<tr>
<td>500.000 1.000.000</td>
<td>20</td>
</tr>
<tr>
<td>250.000 500.000</td>
<td>19</td>
</tr>
<tr>
<td>130.000 250.000</td>
<td>18</td>
</tr>
<tr>
<td>64.000 130.000</td>
<td>17</td>
</tr>
<tr>
<td>32.000 64.000</td>
<td>16</td>
</tr>
<tr>
<td>16.000 32.000</td>
<td>15</td>
</tr>
<tr>
<td>8.000 16.000</td>
<td>14</td>
</tr>
<tr>
<td>4.000 8.000</td>
<td>13</td>
</tr>
<tr>
<td>2.000 4.000</td>
<td>12</td>
</tr>
<tr>
<td>1.000 2.000</td>
<td>11</td>
</tr>
<tr>
<td>500 1.000</td>
<td>10</td>
</tr>
<tr>
<td>250 500</td>
<td>9</td>
</tr>
<tr>
<td>130 250</td>
<td>8</td>
</tr>
<tr>
<td>64 130</td>
<td>7</td>
</tr>
<tr>
<td>32 64</td>
<td>6</td>
</tr>
<tr>
<td>16 32</td>
<td>5</td>
</tr>
</tbody>
</table>
ISO 10/7/5

(NAS 1638: class 1)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>≥ 4 µm(c)</th>
<th>≥ 6 µm(c)</th>
<th>≥ 14 µm(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle count</td>
<td>500 to 1,000</td>
<td>64 to 130</td>
<td>16 to 32</td>
</tr>
</tbody>
</table>
## ISO 12/11/6

(NAS 1638: class 2)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>200 µm(c)</th>
<th>6 µm(c)</th>
<th>14 µm(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle count</td>
<td>2.000 to 4.000</td>
<td>1.000 to 2.000</td>
<td>32 to 64</td>
</tr>
</tbody>
</table>
### ISO 14/13/9

(NAS 1638: class 3)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>≥ 4 µm(c)</th>
<th>≥ 6 µm(c)</th>
<th>≥ 14 µm(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle count</td>
<td>8.000 to 16.000</td>
<td>4.000 to 8.000</td>
<td>250 to 500</td>
</tr>
</tbody>
</table>

[Image of particle count]
ISO 16/14/10
(NAS 1638: class 5)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>≥ 4 µm(c)</th>
<th>≥ 6 µm(c)</th>
<th>≥ 14 µm(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle count</td>
<td>32.000 to 64.000</td>
<td>8.000 to 16.000</td>
<td>500 to 1.000</td>
</tr>
</tbody>
</table>
ISO 17/15/13

(NAS 1638: class 6)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Particle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 4 µm(c)</td>
<td>64.000 to 130.000</td>
</tr>
<tr>
<td>≥ 6 µm(c)</td>
<td>16.000 to 32.000</td>
</tr>
<tr>
<td>≥ 14 µm(c)</td>
<td>4.000 to 8.000</td>
</tr>
</tbody>
</table>
ISO 18/16/13  
(NAS 1638: class 7)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>≥ 4 µm(c)</th>
<th>≥ 6 µm(c)</th>
<th>≥ 14 µm(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle count</td>
<td>130.000 to 250.000</td>
<td>32.000 to 64.000</td>
<td>4.000 to 8.000</td>
</tr>
</tbody>
</table>
### ISO 19/17/14

(NAS 1638: class 8)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Particle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 4 µm(c)</td>
<td>250,000 to 500,000</td>
</tr>
<tr>
<td>≥ 6 µm(c)</td>
<td>64,000 to 130,000</td>
</tr>
<tr>
<td>≥ 14 µm(c)</td>
<td>8,000 to 16,000</td>
</tr>
</tbody>
</table>
## ISO 22/19/17

(NAS 1638: class 10)

<table>
<thead>
<tr>
<th>Particle size</th>
<th>Particle count</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 4 µm(c)</td>
<td>2.000.000 to 4.000.000</td>
</tr>
<tr>
<td>≥ 6 µm(c)</td>
<td>250.000 to 500.000</td>
</tr>
<tr>
<td>≥ 14 µm(c)</td>
<td>64.000 to 130.000</td>
</tr>
</tbody>
</table>
Fatigue wear, 500 x

Sliding wear, 500 x

Cutting wear, 100 x
Cutting wear, 500 x

Dark, shiny metal, 500 x

Copper particles, 500 x
Examples of Contamination | Oil Cleanliness Booklet

Red iron oxide, 500 x

Greasy/resinous residue, 500 x

Seal abrasion, 500 x
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
Oil Analysis Case

- Contamination control for hydraulic fluids and lubricants
- With sampling equipment

Sampling Equipment

- Safe and simple oil sampling from pressure lines and oil containers
Mobile-Particle-Counter
MPC4614

- Light extinction method
- Measurement: oil cleanliness
  ISO 4406/ SAE AS 4059
  4; 6; 14; 21 µm ± 0.5 classes
- Data memory
- Installed battery
- Optional with printer and pump

Datasheet: 51430

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
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

VacuClean® Oil Purification

- Operating data: End vacuum up to 50 mbar
- Oil flow rate: 20 l/min, 5 – 50 l/min, 5 – 80 l/min
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
- Adjustable volume flow: 40 – 150 l/min.
- Filter type: 40 FLE 0270C

Wide Product Range of Filterelements made of paper, metal and fiberglass

- Filtration grade: 1 – 1500 µm
- Filter area: 10 cm² – 4,8 m²

Datasheet: 51420
**Inline Filter**

**Datasheet:**
- 51400  Type 40/100 LEN 0040 to 0400
- 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 0400
- 51423  Type 445 LEN 0040 to 1000

**Tank Mounted Filter**

**Datasheet:**
- 51424  Type 10 TEN 004
- 51425  Type 10 TEN 0160, 0250, 0400, 0630, 1000
**Duplex Filter/Change-Over Inline Filter**

**Datasheet:**
- 51406  Type 50/150 LDN 0040 to 0400
- 51407  Type 40 FLDKN 0063 to 0630
- 51408  Type 40 FLDN 0160 to 1001
- 51409  Type 100 FLDN 0160 to 1000
- 51410  Type 16 FD 2500 to 7500

---

**Manifold Mounted Filter**

**Datasheet:**
- 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
Filter for Mobile Hydraulics

Datasheet:
51426  Type 7SL 30 to 260

Filter for Process Engineering

Type 16 FKE 25/400 to 150/2500
Type 40 FKE 25/400 to 150/2500
Type 16 FKD 25/400 to 150/2500
Type 40 FKD 25/400 to 150/2500

Design coated in Steel and Stainless Steel
The information contained herein is intended to serve purely as a product description. Due to the ongoing development of our products, a statement of a particular aspect or of suitability for a particular purpose cannot be derived from the information provided. This information does not release the user from his responsibility to perform his own assessments and tests. Please note that our products are subject to the natural processes of aging and wear.