A Guide to Contamination Control for Hydraulic and Lubrication Systems
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• Technical innovation
• Premier customer service

Parkers technical resources provide the correct filtration technologies that conform to your requirements. That’s why thousands of manufacturers and equipment users around the world rely on Parker Filtration products and people.

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On-line dynamic particle analysis, off-line bottle sampling and fluid analysis and measurement of water content polluting the oil in a system. All important and achievable, cost-effective solutions available to equipment manufacturers and end users alike.
A guide to contamination control for hydraulic & lubrication systems

The threat of contamination
Industry requirements with regard to hydraulic and oil lubrication systems emphasize reliability, long lifetime and reduced energy use. Depending on the circumstances, some 70 - 80% of system failures are due to contamination. Cleanliness monitoring is essential in contamination control, as is selecting the right filter components. The first step, however, is understanding the specific system requirements and local operating conditions.

This guide to contamination control describes:
- Types of failures
- Sources of contamination
- Fluid cleanliness level
- Condition monitoring equipment
- Cleanliness service
- Filtration: parameters and facts
- Filter selection and filter types

Types of failures
Component failure is often an invisible process. In general three types of failure can be distinguished:

1. Catastrophic failures
   This failure occurs suddenly and without warning; it is of a permanent nature. It is often caused by larger sized particles entering a component and obstructing the relative movement between surfaces, resulting in seizure of the component.

2. Transient failures
   Generally speaking, this type of failure is short-lived and goes unnoticed, although the consequences rarely do. It is caused by particles that momentarily interfere with the function of a component. The particles lodge in a critical clearance between matching parts, only to be washed away during the next operation cycle. As a result, components become less predictable and thus unsafe.

3. Degradation failures
   Gradual deterioration in the performance of a component results in its eventual repair or replacement. This failure is caused by the effect of wear induced by contamination. Additional generated contamination can lead to a catastrophic failure.

Failures or reduced system performance have a direct impact on the Cost of Ownership, the efficiency rate and the perceived quality perception of the end users.
Finding the balance
What does it take to implement system-matched filtration?
A review of the sources of contamination is the first step in finding the balance between the performance of the filtration system and the system demands.

Sources of contamination
Several sources of contamination must be taken into account when it comes to the effective implementation of system-matched filtration. Without adequate filtration the protection of the system is jeopardized and component or system failure is imminent. System-matched filtration changes the deterioration into a balanced situation, representing the continuously controlled process that is needed to achieve system reliability. Realising this is only possible when the required fluid cleanliness levels are maintained.

1. Built-in contamination
Residual contamination from the manufacturing and assembly processes cannot be avoided. Examples are machining debris, weld spatters, casting sand, paint, pipe sealant or fibres from cleaning rags. Flushing system components prior to assembly and decent housekeeping during the various stages of the assembly process are a must to reduce the amount of built-in contamination.

2. Natural contamination
In general, the cleanliness level of new oil does not always meet the requirements of the system. Despite the efforts to control the fluid cleanliness level during the production processes, transport and distribution may contaminate the oil. Depending on the requirements for system cleanliness, we advise that you filter new oil before usage.

3. Ingressed contamination
Systems are always under attack from contamination. Unfortunately it is not possible to avoid ingressed contamination. Air breathers, cylinder rod seals, wiper seals, component seals or poorly fitted covers are a few examples of system parts that may have an important influence on the amount of ingressed contamination.

4. Generated contamination
Particles generate particles. This phenomenon is known as abrasion. Other processes like cavitation, corrosion, erosion, fatigue and metallic contact between moving parts generates particles and thus influences the contamination that is already present in the system. Even though these processes cannot always be avoided, their impact is strongly influenced by effective filtration.

5. Catalytic effect
During the filter selection process, attention is generally given to the removal of solid, hard-type contamination only. The performance of hydraulic and lubrication fluids is influenced by the catalytic effect. As a result of the catalytic effect, the lifetime of the oil is significantly reduced.
Selecting the right oil
Oils are selected based on their unique performance with regard to:

a. Energy transfer
b. Corrosion protection
c. Cooling (transfer of heat)
d. Lubrication

The lifetime of oils is influenced by the amount of oxygen, oil temperature, water content and presence of catalyser type elements. The allowed water content varies for each type of oil. Due to e.g. seal leakage or condensation, the water content can easily reach concentrations far above the allowed water content value. The combination of water and wear elements like iron or copper causes a catalytic effect and as a result, reduces the lifetime of the oil. The lifetime of oil is also influenced by the amount of generated static electricals.

Lifetime reduction
The lifetime reduction of oil is expressed by the degradation factor. The influence of the catalytic effect of the degradation factor is shown below.

System-matched filtration is not limited to a filter alone. The process of system-match filtration is based on the correct implementation of suitable filtration products, taking into account the requirements from the hydraulic or lubrication fluids, system components and customer expectations.

Contamination Control
Achieving the required system protection implicates a correct understanding of the system. Today filters are selected based on several parameters like β-values, pressure drop and dirt holding capacity. Filtration is built-in safety, meant to achieve and maintain the required fluid cleanliness level during a defined period. This implicates a more detailed approach, which can only be realised when several filtration parameters are considered.
Sizes of contamination
Filters are selected to capture contamination from hydraulic and lubrication fluids.

Contamination is an invisible enemy. The human eye cannot see particles smaller than 40 micron. For the correct understanding a comparison is given below.

<table>
<thead>
<tr>
<th>Component</th>
<th>Microns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anti-friction bearings</td>
<td>0.5</td>
</tr>
<tr>
<td>Vane pump (vane tip to other ring)</td>
<td>0.5 - 1</td>
</tr>
<tr>
<td>Gear pump (gear to side plate)</td>
<td>0.5 - 5</td>
</tr>
<tr>
<td>Servo valves (spool to sleeve)</td>
<td>1 - 4</td>
</tr>
<tr>
<td>Hydrostatic bearings</td>
<td>1 - 25</td>
</tr>
<tr>
<td>Piston pump (piston to bore)</td>
<td>5 - 40</td>
</tr>
<tr>
<td>Servo valves flapper wall</td>
<td>18 - 63</td>
</tr>
<tr>
<td>Actuators</td>
<td>50 - 250</td>
</tr>
<tr>
<td>Servo valve orifice</td>
<td>130 - 450</td>
</tr>
</tbody>
</table>

Typical hydraulic component clearances are given as an indication only.

Fluid cleanliness level
The ISO 4406:1999 standard is an important code to define the fluid cleanliness level using a solid contamination code.

This ISO code is determined by allocating a first scale number to the total number of particles larger than 4 µm, allocating a second scale number to all particles larger than 6 µm and allocating a third scale number to the total number of particles larger than 14 µm.

In the recent past, the fluid cleanliness level code was determined using the ISO4406:1987 standard. Instead of counting particles sizes 4, 6 and 14µm, the fluid cleanliness level was determined by counting particles larger than 5 and 15µm. The particle size 2 µm was added later.

As a result of upgrading the ISO standards, new particle sizes have been defined. In general, the fluid cleanliness code will not change as a result of this new standard. Built-up historic data remains directly comparable to new data.
Examples of cleanliness level are given in the ISO graph. These lines represent:

A. Low-pressure systems (code 21/20/17)
B. Low-pressure control systems (code 19/18/14)
C. Sophisticated pumps/motors control valves (code 18/17/13)
D. Highly sophisticated systems and hydrostatic transmissions (code 16/15/11)
E. Sensitive servo systems (code 15/14/10)
F. High performance sensitive systems (code 12/11/8)

We recommend verifying the required cleanliness level based on the components used for the system. Manufacturers of system components often provide information related to the required fluid cleanliness level for their products.

**Condition monitoring equipment**

Over the years, fluid condition monitoring has become increasingly important. By offering system-matched filtration solutions, the stringent customer demands related to extended component lifetime or improved system reliability can be met. Parker has developed a complete range of instruments and components for maintenance programmes and local fluid condition analysis such as the LaserCM below.

Parker’s particle counters are well known for their accurate performance in the field or in a production line environment. Lightweight portable particle counters can be used for temporary fluid cleanliness measurements. The MCM20, designed for permanent installation, is meant for continuous fluid monitoring. Just recently, the compact MS100 moisture sensor was introduced. Together with the H2Oil module, a complete unit is available to measure the water content of hydraulic or lubrication fluids.

**Solid contaminant codes**

In addition to ISO 4406: 1999, other standards are used to express the fluid cleanliness level. A comparison between the codes is given below.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>13/11/8</td>
<td>11/8</td>
<td>2</td>
</tr>
<tr>
<td>14/12/9</td>
<td>12/9</td>
<td>3</td>
</tr>
<tr>
<td>15/13/10</td>
<td>13/10</td>
<td>4</td>
</tr>
<tr>
<td>16/14/9</td>
<td>14/9</td>
<td>-</td>
</tr>
<tr>
<td>16/14/10</td>
<td>14/10</td>
<td>5</td>
</tr>
<tr>
<td>17/15/9</td>
<td>15/9</td>
<td>-</td>
</tr>
<tr>
<td>17/15/10</td>
<td>15/10</td>
<td>-</td>
</tr>
<tr>
<td>17/15/12</td>
<td>15/12</td>
<td>6</td>
</tr>
<tr>
<td>18/16/10</td>
<td>16/10</td>
<td>-</td>
</tr>
<tr>
<td>18/16/11</td>
<td>16/11</td>
<td>-</td>
</tr>
<tr>
<td>18/16/13</td>
<td>16/13</td>
<td>7</td>
</tr>
<tr>
<td>19/17/12</td>
<td>17/12</td>
<td>-</td>
</tr>
<tr>
<td>19/17/14</td>
<td>17/14</td>
<td>8</td>
</tr>
<tr>
<td>20/18/12</td>
<td>18/12</td>
<td>-</td>
</tr>
<tr>
<td>20/18/13</td>
<td>18/13</td>
<td>-</td>
</tr>
<tr>
<td>20/18/15</td>
<td>18/15</td>
<td>9</td>
</tr>
<tr>
<td>21/19/13</td>
<td>19/13</td>
<td>-</td>
</tr>
<tr>
<td>21/19/16</td>
<td>19/16</td>
<td>10</td>
</tr>
<tr>
<td>22/20/13</td>
<td>20/13</td>
<td>-</td>
</tr>
<tr>
<td>22/20/17</td>
<td>20/17</td>
<td>11</td>
</tr>
</tbody>
</table>

**Note:**

ISO 4406: 1987 is based on particle sizes larger than 5 and 15 µm
ISO 4406: 1999 is based on particles sizes larger than 4, 6 and 14 µm

**Several cleanliness levels**
A guide to contamination control for hydraulic & lubrication systems

Cleanliness service to prevent failures
As Parker has no financial interest in the oil industry, the company can operate as an independent laboratory. The development laboratory Parker Filtration BV in Arnhem - the only laboratory of its kind in Belgium, the Netherlands and Luxembourg - has at its disposal all the facilities for its extensive R&D department. In addition, the services are offered on a commercial basis to third parties.

Equipment
The laboratory uses state-of-the-art test equipment. Just recently, the company invested in the latest Karl Fischer coulometric equipment, that prevents tests from being influenced by, among other things, additives in the oil. The particle-counting equipment is calibrated according to the recently renewed ISO 11171 standard. It is now possible to indicate the measured cleanliness according to ISO 4406:1999. A number of the laboratory facilities are accredited by the Dutch national Board of Accreditation as an independent ISO 17025 STERLAB organisation.

Standard test
The high-quality standard test, carried out in Parker’s laboratory, consists of a water analysis and a cleanliness calculation according to ISO 4406, the new ISO 4406:1999 and the NAS 1638 standard, as part of which particles from 2 to 100µm are measured and reported. Membrane research and digital photography of the membrane are also part of the standard test. The results of each test are described in a report that contains clear conclusions. It is also possible to conduct a spectral analysis.

In practice
How do the laboratory services work? Only three days after receipt of the oil sample, the standard analysis is completed. The results of a spectral analysis are known after seven days. The reports can be sent directly and completely by e-mail. A free sample bottle is available upon request.

Filtration: parameters and facts
Generally speaking, fibre-type materials like cellulose and glass fibre are applied for hydraulic and lubrication fluid filtration. Filters are selected based on the following parameters:

- Required protection of system components
- Location of filter(s) in the system
- Flow rate and allowed pressure loss
- Desired filter element life time
- Hydraulic or lubrication fluid type

The dirt holding capacity is the amount of solid contamination a filter can hold before this contamination is removed. This value is measured in accordance to ISO16889 using ISO MTD test dust. The filter element lifetime strongly depends on the contamination conditions that are present in the system and its environment.

Predicting the filter element lifetime in the system is complicated, because of the variety in contamination (e.g. metal, sand and fibres, each with a certain distribution of particle sizes) in relation to the specified dirt holding capacity.

Degree of filtration
Parker’s filtration philosophy is based on the optimum distribution of several particle sizes by using the complete thickness of glass fibre layers.

Pre-layer

Main layer

Each selected filter layer has a unique performance for the removal of solid contamination. System-matched filtration implicates the removal of harmful particles. For some systems an improved removal efficiency for smaller sized particles is more important compared to other systems using components. The combination of pre- and main layers results in an achievable fluid cleanliness level. The complete package of filter and support layers is indicated as pleat pack.
The $\beta$-value is used to express the removal efficiency for a defined particle size.

\[
\beta(x) = \frac{N \text{ particles upstream } > x \ \mu m}{N \text{ particles downstream } > x \ \mu m}
\]

The ISO 4572 standard formerly required only the $\beta_x>75$ value. That standard has now been upgraded and replaced by ISO16889, reporting the $\beta$-value of 2, 10, 75, 100, 200 and 1000 for each filter medium or pleat pack. The corresponding efficiencies are given below.

<table>
<thead>
<tr>
<th>$\beta$-value</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>50.00%</td>
</tr>
<tr>
<td>10</td>
<td>90.00%</td>
</tr>
<tr>
<td>75</td>
<td>98.67%</td>
</tr>
<tr>
<td>100</td>
<td>99.00%</td>
</tr>
<tr>
<td>200</td>
<td>99.50%</td>
</tr>
<tr>
<td>1000</td>
<td>99.99%</td>
</tr>
</tbody>
</table>

Taking into account a $\beta_{75}(c)>10$ element, the removal efficiency is 98.67% of particles larger than 10 micron.

Too often filter elements are compared by looking at one $\beta$-value only. The focus on high $\beta$-values is misleading and does not always provide the required information.

<table>
<thead>
<tr>
<th>Comparison $\beta$-value</th>
<th>Filter element I</th>
<th>Filter element II</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_{75}(c)&gt;10$</td>
<td>5,000,000</td>
<td>5,000,000</td>
</tr>
<tr>
<td>Number of particles &gt;10 micron</td>
<td>98.67%</td>
<td>99.50%</td>
</tr>
<tr>
<td>Removal efficiency</td>
<td>98.67%</td>
<td>99.50%</td>
</tr>
<tr>
<td>Number of particles &gt;10 micron</td>
<td>66,500</td>
<td>25,000</td>
</tr>
</tbody>
</table>

Statements that a $\beta_{200}$ filter improves the fluid cleanliness level by a factor 2.6 ($\frac{66,500}{25,000}$) are misleading. Fluid cleanliness codes are based on several particle sizes. More information is needed to determine the overall removal performance of filter media.

A comparison between two 10-micron filter medias.

The overall removal efficiency of the element forms the core of fluid cleanliness levels.

The correct degree of filtration is chosen based on the required fluid cleanliness level, not based on one $\beta$-value.

<table>
<thead>
<tr>
<th>Components</th>
<th>ISO Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servo control valves</td>
<td>16/14/11</td>
</tr>
<tr>
<td>Proportional valves</td>
<td>17/15/12</td>
</tr>
<tr>
<td>Valve &amp; piston pumps/motors</td>
<td>18/16/13</td>
</tr>
<tr>
<td>Directional &amp; pressure control valves</td>
<td>18/16/13</td>
</tr>
<tr>
<td>Gear pumps/motors</td>
<td>19/17/14</td>
</tr>
<tr>
<td>Flow control valves</td>
<td>20/18/15</td>
</tr>
<tr>
<td>Cylinders</td>
<td>20/18/15</td>
</tr>
</tbody>
</table>

An indication of recommended fluid cleanliness levels is given in this table. It is common use in the industry that manufacturers of components prescribe required fluid cleanliness level for the reliable functioning of their products.

The ISO codes are indicative values only.

Filter media composition.
Flow rate and allowable pressure lost

Each filter element is designed to handle a nominal flow rate. The allowed flow rate depends on fluid viscosity, degree of filtration, and the amount of pressure that is lost. Indirectly, the required element lifetime is an important parameter. A larger sized element with a more effective filter element area has a positive influence on the element lifetime.

<table>
<thead>
<tr>
<th>Media</th>
<th>Degree of Filtration</th>
<th>Upper Range</th>
<th>Lower Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>3</td>
<td>16/14/10</td>
<td>13/11/8</td>
</tr>
<tr>
<td>Q3</td>
<td>6</td>
<td>18/16/13</td>
<td>17/15/9</td>
</tr>
<tr>
<td>Q5</td>
<td>10</td>
<td>20/18/15</td>
<td>19/17/12</td>
</tr>
<tr>
<td>Q10</td>
<td>20</td>
<td>22/20/17</td>
<td>21/18/13</td>
</tr>
</tbody>
</table>

The given cleanliness levels are indicative values only, based on average values.

Filter elements are chosen based on their initial clean element pressure drop. It is preferred to apply a ratio of at least three between element bypass settings and element initial pressure drops.

Comparing filter elements with different filter media based on the initial clean element pressure drop does not give a reliable indication of the element dirt holding capacity. In this example the filter media A has a higher initial pressure drop. However, during its lifetime the pressure lost is more constant compared to media B. This results in a longer element lifetime. The difference in performance is caused by a more effective distribution of captured particles in media A.

Filter types and locations

Depending on the filter type and corresponding location, a general pressure lost recommendation can be given:
- Suction line: 0.03-0.05 bar
- Pressure line: 1 bar
- Return line: 0.3-0.5 bar
- Suction return filter: 1 bar

![Life time diagram](image-url)
It's better to be safe than to be sorry

The selection and proper use of filtration devices are essential in the battle to increase production while reducing manufacturing costs. Properly sized, installed and maintained hydraulic filtration plays a key role in machine preventative maintenance planning. Parker Filtration offers the air, gas and liquid filtration products that meet and exceed your requirements.

But, the services of Parker go well beyond development and production. To reduce the chance of breakdown and to make system components and oil last longer, Parker also provides condition monitoring equipment, including LaserCM for on-site monitoring and permanent, built-in monitoring devices.

Moreover, Parker offers the analyses of the cleanliness and condition of hydraulic oil as well as supporting services that include professional support in the field (on-site advice), filter research, trainings and seminars in the field of cleanliness and system maintenance.

Based on extensive know-how and experience, Parker offers products, system solutions and services that make us… ‘Your Partner for Filtration’.
The Choice is Perfectly Clear

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