Measurement of Residual Particulate Contamination on Components
Component Cleanliness – Introduction

Measurement of residual particulate contamination on components is increasingly becoming a requirement for manufactures.

These measurements can predict future component reliability, provide conformance to customer cleanliness specifications and monitor performance of current component cleaning processes.
Component Cleanliness - Measure to control

Measurement allows us to ensure that processes are capable and in control.

Component cleanliness is measured to a given standard, against a given specification.

The standard describes how to test a component, and how to report the findings. This is to ensure the test is repeatable and meaningful.

The specification is the value of the desired result, the maximum level of dirt allowed, and is specific to the component.
Component Cleanliness - Specifications

Most companies develop or are asked to meet component cleanliness specification based on

Gravimetric Levels – mg per part or surface area
- 1.2 mg/part or 1.2 mg/1000 cm²

Maximum particle size assessment
- no particles > 100 µm

Particle size distribution
- 30 particles > 50 µm
- 5 particles > 100 µm
- 1 particles > 500 µm
Component Cleanliness - Standards

The most commonly used international standard is ISO 16232 Road Vehicles - Cleanliness of components of fluid circuits

Other standards exist for example ISO 18413 – Hydraulic fluid power – Component cleanliness – Sample collection, analysis and data reporting
ISO 16232 – General overview

**Inspection:** Component / system

**Extraction:**
- Agitation
- Pressure rinsing
- Ultrasonic
- Test bench

**Analysis:**
- Gravimetry
- Microscopy
- SEM-EDX
- Counting *

**Reporting:** Component Cleanliness Code

Select one method

* Automatic Particle Counting
ISO 16232 – Extraction method by agitation (slosh test)

Main parameters impacting the effectiveness of the agitation method:
- Type of agitation
- Choice of the test liquid
- Duration of agitation
- Amplitude of agitation
ISO 16232 – Extraction method by pressure rinse (example)

Main parameters impacting the effectiveness of the pressure rinse method:

- Pressure
- Distance
- Geometry of the nozzle
- Flow rate
- Volume of solvent
- Solvent properties

Often particles adhere to a surface helped by moisture, grease, oil, etc.
ISO 16232 – Extraction method by Ultrasonic techniques
(mainly used for small components)

Main parameters impacting the effectiveness of the ultrasonic method:
- Power of vibrations
- Frequency
- Duration of the vibrations
- Types of applications (bath, sonotrode)
ISO 16232 – Extraction method by ‘end-use simulation’

Functional test bench
(flushing under pressure)

**Simplified schematics**

![Simplified schematics diagram]

Main parameters impacting the effectiveness of the end-use simulation method:
- Flow rate
- Flow condition
- Component geometry
- Test fluid
- Viscosity
- Test rig design (flushing under pressure or vacuum)
Extraction Equipment

Pans and Funnels

Stainless steel pans and filter funnels are used to collect contamination rinsed off parts.

Solvent dispensing tanks are used to supply solvent.

Equipment open to atmosphere and prone to background contamination
Cleanliness Cabinet
Cleanliness Cabinets provide a controlled, clean environment to ensure that tests are repeatable by controlling the air quality in a laminar flow HEPA filtered cabinet, and by using a defined set volume of filtered solvent for each test.

The Cleanliness Cabinet can clean itself between tests to ensure that the “blank value” (background contamination level) is within specification.

“Blank”:
Analysis performed with the same procedure but without the component. The blank test qualifies the background of the overall procedure (environment, method & equipment).
Blank Value

Use of extraction methods to inspect the cleanliness of components involves the risk background particles are introduced into the test.

If the background particles (blank level) are too high, this could lead to a faulty assessment of component cleanliness.

The blank level represents the total value of contamination that does not originate from the component.
Background Contamination Sources

Test fluid

Extraction equipment (baths, basins, tubing, valves, etc.)

Objects coming into contact with the component and test liquid

Handling processes during preparation, extraction and analysis

Environment

The blank level may not exceed 10% of the required/expected cleanliness values for the component
ISO 16232 – Validation of the extraction method

Determine the volume of fluid and procedure required for testing each specific type of component – ‘the 90% rule’

The same component is measured many times using the same method until 90% of the contaminants are extracted

This is achieved when a result of any single test is 10% or less of the total sum achieved in all tests
ISO 16232 – Validation of the extraction method

Example:
A component was measured using the same volume of solvent (1 L) for each test.
The results are shown below.
On the fifth measurement, the result was <10% of the sum total of all the tests.
Therefore, the fluid volume required to test the component is defined as 5 x 1 L = 5 L.

If six extractions have been performed without reaching a value ≤ 10%, then the extraction parameters must be modified.
## Component Cleanliness Measurement – Extraction Example

<table>
<thead>
<tr>
<th>Part #</th>
<th>Membrane</th>
<th>Rinse volume</th>
<th>Initial membrane weight</th>
<th>Final membrane weight</th>
<th>Net membrane weight</th>
<th>Percent remaining based on previous extractions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2,000 ml</td>
<td>123.1 mg</td>
<td>132.2 mg</td>
<td>9.1 mg</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2,000 ml</td>
<td>123.5 mg</td>
<td>125.5 mg</td>
<td>2.0 mg</td>
<td>22.0%</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2,000 ml</td>
<td>123.0 mg</td>
<td>123.6 mg</td>
<td>0.6 mg</td>
<td>7.7%</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>6,000 ml</td>
<td>123.3 mg</td>
<td>134.3 mg</td>
<td>11.0 mg</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6,000 ml</td>
<td>123.6 mg</td>
<td>124.3 mg</td>
<td>0.7 mg</td>
<td>6.4%</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>6,000 ml</td>
<td>123.0 mg</td>
<td>134.1 mg</td>
<td>11.1 mg</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>6,000 ml</td>
<td>123.0 mg</td>
<td>123.8 mg</td>
<td>0.8 mg</td>
<td>7.28%</td>
</tr>
</tbody>
</table>
Apart from the automatic particle counting method, the 3 techniques used to quantify and qualify solid contaminant levels require a filter membrane.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Standard equipment</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravimetry</td>
<td>Laboratory balance</td>
<td>Mass of contaminants</td>
</tr>
<tr>
<td>Microscopy</td>
<td>Image analyzer</td>
<td>Particle counting</td>
</tr>
<tr>
<td>Microscopy</td>
<td>MEB-EDX *</td>
<td>Nature of contaminants</td>
</tr>
</tbody>
</table>

* Scanning Electron Microscope associated with a X-ray detection system
The Microscope Imaging System is a complete system to size and count particulate contamination on analysis membranes.

System includes microscope, digital camera, computer, software, setup and training. The system will automatic scan back to specific particles for examination.

All images and test conditions are saved for future reference. The unit is ISO 16232 compatible.
Setting Up Component Cleanliness Testing Procedure

Determine specifications that need to be met
  - Gravimetric
  - Particle size and distribution
Determine equipment to extract contamination – Pans and funnels,
Cleanliness Cabinet, Other
  - Meet extraction validation requirements
  - Consistant blank values
Determine analysis equipment
  - Ovens and scales
  - Microscope imaging systems