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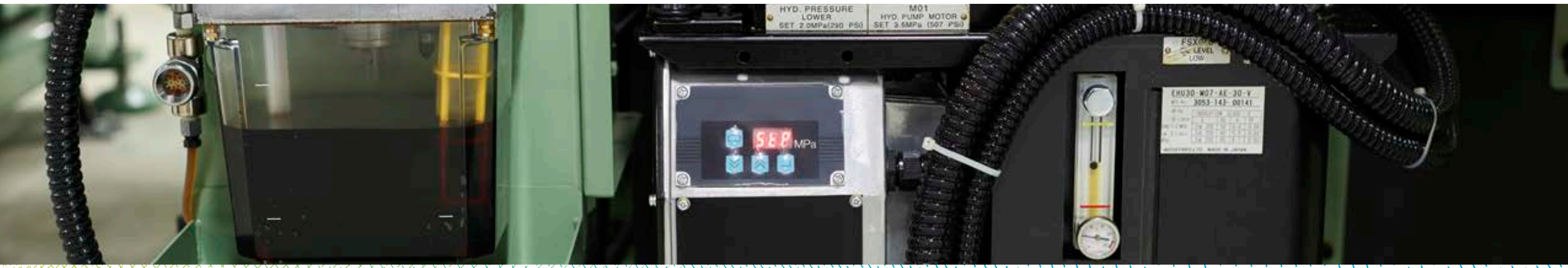
How to ensure proper oil cleanliness in lubrication systems



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Introduction

Maintaining proper oil cleanliness is critical to the success of any industrial operation. Oil contamination from particulate matter accelerates the rate of component wear and can lead to premature component failure. In fact, oil contamination is linked to more than 75 percent of all industrial equipment failures.

Ensuring oil cleanliness can help mitigate these issues and lead to longer equipment life, less unscheduled downtime and reduced maintenance costs.

What is oil cleanliness?

Oil cleanliness is a measure of the level of particle contaminants in the oil, including both insoluble and hard particles. Acceptable oil cleanliness levels are often determined by Original Equipment Manufacturer (OEM) recommendations and can be controlled through proactive maintenance methods.

It is particularly important to maintain oil cleanliness in applications with tight clearances (such as equipment with servo valves) or harsh operating conditions (such as extreme temperatures, pressures or speed).

Factors that contribute to oil contamination

There are two main sources of oil contamination:

External sources: these include foreign particles such as dirt, dust and other particulate matter that enter into the system.

Internal sources: these include wear particles that contaminate the oil as a result of mechanical wear.

There are four main types of mechanical wear: abrasive, fatigue, adhesive and erosive. The table below provides more detail on each type of wear and outlines their effect on equipment performance.

Wear type	Direct effects
Abrasive: particles in the clearance between moving surfaces remove material from the surface	Dimensional change
	Leakage
	Lowering efficiency
Adhesive: two metals rub together – leading to an instantaneous welding of the surface – and the continuous motion leads to the break of the welded points, causing generated wear metals	Metal-to-metal contact points
	Cold welding
	Adhesion and shearing
Fatigue: repeated stress caused by the clearance surface particles trapped by the moving surfaces	Deterioration of finish surface
	Leakage
	Cracks
Erosive: particles impinge on a component surface of edge and removing material due to momentum effects	Slow response
	Spool jamming
	Solenoid burnout

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How do you measure oil cleanliness?

Oil cleanliness is measured against ISO Cleanliness Code 4406. This code quantifies particulate contamination levels per milliliter of oil at 4, 6 and 14 μm.

The first step in measuring oil cleanliness is counting the particulate matter using one of several particle counting methods.

These include:

ISO 4407: In this method, the oil sample is passed through a very fine filter patch to capture particles. An optical microscope is then used to count the particles that are between 5 and 15 μm. This method was one of the original methods used for particle counting, but it is extremely time-consuming and is rarely used today.

ISO 11500: This method, which is the most widely deployed method today, uses an optical particle counter. A laser or white light is focused on a capillary detection zone. As the oil sample passes through the detection zone, the particles create a shadow on a photocell detector. The drop in voltage produced by the photocell then helps determine the size of the particles passing through. Any particles greater than 4, 6 and 14 μm are counted. Because the test is fully automated, results are processed quickly.

ASTM D7647-10: This method uses the same laser equipment as the ISO 11500 method, but the test sample is pre-treated with solvent dilution techniques. These techniques can eliminate some of the "soft particles," enabling operators to instead count hard particles that have the most significant impact on equipment wear. However, this test is more time-consuming than the ISO 11500 method.

Regardless of the test method used, it's critical to take a relevant and representative sample when measuring particle counts to properly determine the contamination level. Incorrect sampling can adversely affect the cleanliness level in the sample bottle, which will skew results and lead to incorrect insights.

Determining the level of contamination

Once operators have accurately measured the particle count, they should then use the ISO 4406 classification to determine the contamination level.

As mentioned previously, the ISO Cleanliness Code quantifies particulate contamination levels per milliliter of fluid at three sizes: 4, 6 and 14 μm. The code is expressed in three numbers, which represent the respective contaminant level code for the correlating particle size. The code includes all particles of the specified size and larger.

How do you determine the proper Oil Cleanliness Code target?

The best way to determine an Oil Cleanliness Code target for a given piece of equipment is to reference the Table of recommended target ISO Cleanliness Codes and selection of media for systems using petroleum based fluids per ISO 4406, which is shown below. This table helps determine the level of cleanliness required for each application as well as the filtration required to maintain it.

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Table of recommended* target ISO Cleanliness Codes and selection of media for systems using petroleum based fluids per ISO 4406:1999 for particle sizes 4µm[c]/6µm[c]/14µm[c]

Equipment	Pressure <140 bar <2000 psi	Media βx[c] = 1000 (βx = 200)	Pressure 140<P <212 bar 2000<P<3000 psi	Media βx[c] = 1000 (βx = 200)	Pressure >212 bar >3000 psi	Media βx[c] = 1000 (βx = 200)
Pumps						
Fixed gear	20/18/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)	-	-
Fixed piston	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)	17/15/12	7µm[c] (6µm)
Fixed vane	20/18/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)
Variable piston	18/16/13	7µm[c] (6µm)	17/15/12	5µm[c] (3µm)	16/14/11	7µm[c] (6µm)
Variable vane	18/16/13	7µm[c] (6µm)	17/15/12	5µm[c] (3µm)	-	-
Valves						
Cartridge	18/16/13	12µm[c] (12µm)	17/15/12	7µm[c] (6µm)	17/15/12	7µm[c] (6µm)
Check valve	20/18/15	22µm[c] (25µm)	20/18/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)
Directional (solenoid)	20/15/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)
Flow control	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)	17/15/12	12µm[c] (12µm)
Pressure control (modulating)	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)	16/14/11	7µm[c] (6µm)
Proportional cartridge valve	17/15/12	7µm[c] (6µm)	17/15/12	7µm[c] (6µm)	16/14/11	5µm[c] (3µm)
Proportional directional	17/15/12	7µm[c] (6µm)	17/15/12	7µm[c] (6µm)	16/14/11	5µm[c] (3µm)
Proportional flow control	17/15/12	7µm[c] (6µm)	17/15/12	7µm[c] (6µm)	16/14/11	5µm[c] (3µm)
Proportional pressure control	17/15/12	7µm[c] (6µm)	17/15/12	7µm[c] (6µm)	16/14/11	5µm[c] (3µm)
Servo valve	16/14/11	5µm[c] (3µm)	16/14/11	5µm[c] (3µm)	15/13/10	5µm[c] (3µm)
Bearings						
Ball bearing	15/13/10	5µm[c] (3µm)	-	-	-	-
Gearbox (industrial)	18/16/13	12µm[c] (12µm)	-	-	-	-
Journal bearing (high speed)	17/15/12	7µm[c] (6µm)	-	-	-	-
Journal bearing (low speed)	17/15/12	7µm[c] (6µm)	-	-	-	-
Roller bearing	16/14/11	5µm[c] (3µm)	-	-	-	-
Actuators						
Cylinder	17/15/12	7µm[c] (6µm)	16/14/11	5µm[c] (3µm)	15/13/10	5µm[c] (3µm)
Vane motor	20/18/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)
Axial piston motor	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)	17/15/12	7µm[c] (6µm)
Gear motor	20/18/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)
Radial piston motor	20/18/15	22µm[c] (25µm)	19/17/14	12µm[c] (12µm)	18/16/13	12µm[c] (12µm)
Test stands, hydrostatic						
Test stand	15/13/10	5µm[c] (3µm)	15/13/10	5µm[c] (3µm)	15/13/10	5µm[c] (3µm)
Hydrostatic transmission	17/15/12	7µm[c] (6µm)	16/14/11	5µm[c] (3µm)	16/14/11	5µm[c] (3µm)

**Depending upon system volume and severity of operating conditions, a combination of filters with varying degrees of filtration efficiency might be required to achieve and maintain the desired fluid cleanliness. Filters are rated according beta ratio* $\beta_{x[c]}$ *at specific particles size* $X_{\mu m}$*:*

$$\beta_{x[c]} = \frac{n_{\text{upstream} \geq X\_\mu m}}{n_{\text{downstream} \geq X\_\mu m}}$$

Efficiencies are measured in multi pass test; the higher the number, the more efficient the filter at a given micron size.

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How do you determine the proper Oil Cleanliness Code target? (cont.)

When using this table as a reference, operators should follow some basic guidelines to ensure the proper targets are selected:

- The target selection criteria should be based on the most sensitive component in the lubrication system, particularly when using a central reservoir to supply several systems.
- When using a non-petroleum based fluid or water-based lubricant (e.g., water glycols), use a target ISO Cleanliness Code that is one value lower than in the table.
- Select a target ISO Cleanliness Code that is two values lower than shown if the equipment operates under frequent cold starts, excessive shock or vibration, or if the component is critical to system reliability.

Following these guidelines can help ensure optimal equipment reliability and safety, resulting in:

- Reduced repair and replacement costs
- Extended oil life
- Adherence to equipment warranty requirements
- Reduced production downtime

How do you achieve and maintain proper oil cleanliness?

After selecting the appropriate target ISO Cleanliness Code for the application, there are several considerations to achieve and maintain the desired cleanliness:

- Filter micron rating
- Filter efficiency (Beta Ratio)
- Filter size
- Full flow or side stream
- Filtration placement:
    - Filtration when the lubricant is received
    - Filtration as lubricant is dispensed
    - Filtration at set interval or based on oil analysis with portable filtration units
    - Permanent filtration installed directly on the equipment

Storage and handling

Lubricants become vulnerable to contamination during storage, and especially when handled or moved. This makes receiving certified clean oil the least efficient manner in achieving desired cleanliness, unless it is being delivered directly to the application.

A sealed container is still susceptible to ingress contamination of particles and water as air temperature around the container rises and falls.

In order to reduce contamination during storage:

- Store lubricants in sealed containers that reside in a sheltered room or building.
- Equip containers with air and water filtration.
- Drums should be stored horizontally with large and small bungs in 3 and 9 o'clock positions.
- Close bungs promptly after use.

Dispensing and in-service

Lubricant dispensing and in-service in the equipment is the most critical step in achieving and maintaining desired oil cleanliness. These are the last points before the lubricant comes into contact with the critical wear components.

In order to achieve and maintain proper oil cleanliness, operators should follow these dispensing and servicing best practices:

- Always use dedicated pumps, carts and hoses to dispense the lubricant.
- The dispensing pump/cart should be equipped with the appropriate filtering media size and efficiency when filling and topping up oil charges.
- Always clean the filling cap before removing it prior to filling the reservoir.
- Change the media filter when the OEM recommended maximum pressure differential has been reached.
- Ensure that the oil reservoir is closed (no open cover plate) and the filler cap should always be in place.
- Always equip the breather on the reservoir with an air filter. Depending on the sensitivity of the application, equip the reservoir with a media that removes water as well.

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- Implement a used oil analysis program to monitor the in-service oil condition and ensure it meets the target ISO Cleanliness Code.
- Control oil leakage, as more frequent oil top-offs expose the application to greater risk of contaminant ingression.

Conclusion

Maintaining proper oil cleanliness is about more than just using the right lubricants – it's also about taking the right steps to ensure a clean operating environment that helps minimize the risk of particulate contamination.

More specifically, operators should implement a programmatic lubrication approach built around regular assessments. These programs should:

Establish limits:
Operators should use the techniques outlined in this article to determine the acceptable cleanliness limits required for the application. They should then use proper filtration to further reduce risk of contamination.

Identify and address ingress sources:
Operators must be vigilant about maintaining a clean operation that minimizes lubricant exposure to contaminants. This includes ensuring proper storage and handling practices as well as following the right protocols during lubricant dispensing and equipment servicing.

Implement regular used oil analysis:
By implementing a regular used oil analysis program, operators can better monitor lubricant cleanliness levels and quickly identify any potential warning signs of contamination.

By following these guidelines, operators can help maintain proper oil cleanliness, helping extend equipment life and enhance operational productivity.

References

NAS 1638 "Cleanliness requirements of parts used in Hydraulic systems," Aerospace Industries of America, Washington D.C., USA, 2001.

ISO 4406 "Hydraulic fluid power - Fluids - Method for coding level of contamination by solid particles," International Organization for Standardization, Geneva, Switzerland, 1999

ISO 4407 "Hydraulic Fluid Power - Fluid Contamination - Determination of Particulate Contamination by the Counting Method Using an Optical Microscope," International Organization for Standardization, Geneva, Switzerland, 2002

ISO 11500 "Hydraulic fluid power — Determination of the particulate contamination level of a liquid sample by automatic particle counting using the light-extinction principle," International Organization for Standardization, Geneva, Switzerland, 2008

Mike Day, Pall Corporation "What Happened to NAS 1638?" Practicing Oil Analysis Magazine, November 2002

Henri Braun, Dr. Tim Nadisdi, Sandra Legay, ExxonMobil Fuels, Lubricants & Specialties Marketing Co. "Oil Cleanliness & Filtration" – Presented in Society of Tribologists and Lubrication Engineers Annual Meeting & Exhibition, Saint Louis, Missouri, USA, May 2012

Bernie Koenitzer, Clint Smith Imperial Oil Ltd. Alex Bolkhovsky and Dr. Tim Nadasdi ExxonMobil "Lubricants & Specialties: Do we really know what we are measuring?"- Maintenance Technology 2007

Precision Filtration Products: Selecting target ISO Cleanliness Code

Vickers: Hydraulic Hints & Trouble Shooting Guide

Pall Corporation Pocket Book – Filtration. Separation. Solution, Jan 2011

C.C.JENSEN, Clean Oil Guide: The importance of Oil Maintenance, Feb 2015

Dr. Robert M. Gresham STLE's Director, Contamination Control – Eliminating contamination is impossible but this three-step system will help you regulate it

Exxon Mobil Corporation Technical Topics, 2009
- *Handling & Storing Lubricants*
- *Hydraulic System Care and Maintenance*