ISO Cleanliness Requirements

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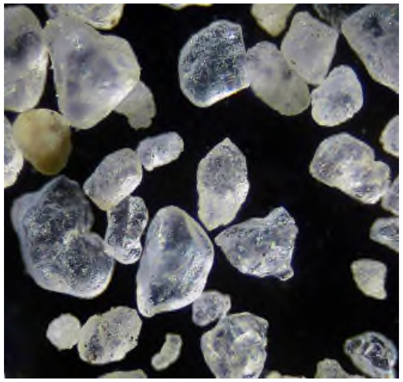
Agenda

- Contamination Control
- Contamination Prevention
- Contamination Measurement
- Particle Counting
- NAS 1638 and ISO 4406
- Equipment Life Extension
- Filtration Basics
- Cleanliness Requirements for Various Applications

Contamination Control

- **Contamination Control** had different meanings to different people.
- In terms of lubricants, **contamination** means anything that is in the lubricant that is foreign to the finished lubricant formulation.
- Examples of contaminants include water, dirt, air, undissolved additives, plastic particles, metal shavings, fibers, and carbon particles.
- The term **control** means either excluding or removing anything that may get in or already be in the lubricant that is foreign to the formulation.



Contamination Prevention

- The simplest approach to contamination control is prevention of the ingress of contaminants into the lubricant. Contamination prevention may consist of any of the following:
- Cleanliness standards for raw materials
- Good lubricant storage and handling practices
- Good maintenance practices to prevent contaminant ingress
- Product packaging cleanliness, both new containers and during filling
- Prevent contaminant ingress during packaging
- Ensure cleanliness of bulk transport trailers and totes
- Proper storage of filler containers

Contamination Measurement

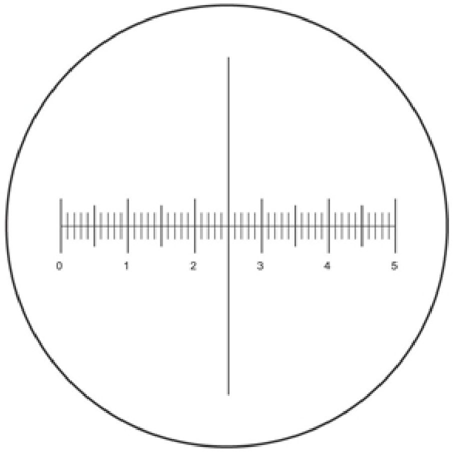
- Sampling technique is critical to obtaining a representative sample for particle count testing.
- The sample container must be clean (special clean containers are available).
- The sample point should be dedicated for the purpose and capped or plugged when not in use.
- The sample point should be cleaned before each sample is obtained. Environmental contaminants must be excluded.
- The sample must be tightly closed to prevent ingress of atmospheric particles.

Contamination Measurement

- Once in the laboratory, the sample should be shaken or sonicated to evenly distribute particles throughout the sample.
- Testing should proceed immediately in order for the results to best represent the true number of particles in the sample.
- The use of a bottle sampler that deaerates the sample prior to testing is preferred, to remove air bubbles that can be counted as particles.
- Consistent sampling and testing techniques are necessary to produce results that are suitable for trending.

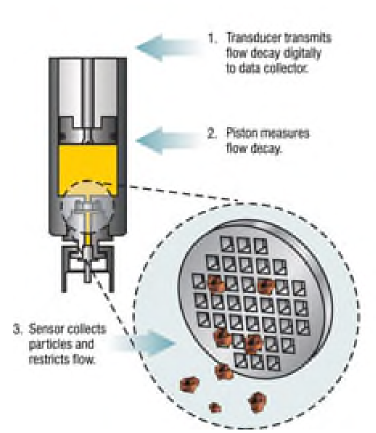
Particle Counting

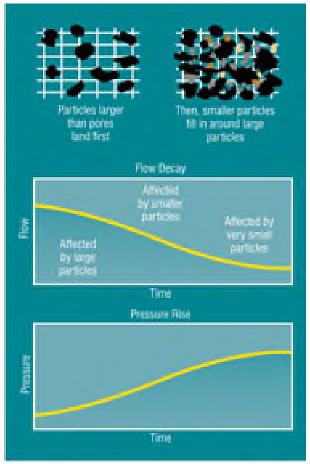
- There are several methods for counting particles in lubricants:
- On optical microscopy, the sample is placed on a microscope slide and examined under a microscope with an eyepiece fitted with a reticle. Particles are manually counted. It is labor intensive and tedious. ASTM D2390 and SAE ARP-598.
- Patch testing (ASTM D2276) coupled with optical microscopy has been used for particle counting. Labor intensive and subject to operator technique.



Particle Counting

- Automatic particle counters automate the testing process and remove operator technique as a testing variable.
- Flow decay or mesh blockage particle counters work on the principle that the change in the differential pressure across a fine filter element is mathematically related to the size of particles captured on the mesh. They are not affected by air bubbles, water, or other liquid contaminants. The filter element eventually becomes blocked, affecting accuracy, and must be cleaned.





Particle Counting

- Light extinction particle counters come in several models, with flow-through cells for on-line operation or use with a bottle sampler. Models based on white light bulbs and lasers have been developed. Both count particles by measuring the intensity of light reaching a sensor from the source. Accuracy can be affected by the opacity of the fluid, the color of the sample, the refractive index of the fluid and particles, the particle loading of the sample, and the particle size distribution.

National Aerospace Standard (NAS) 1638

- NAS 1638 (2001) has been effectively replaced by SAE AS4059E (2005). However, NAS 1638 is still cited in many specifications. Cleanliness is classified by the number of particles per 100 mL in various size classes.

National Aerospace Standard 1638 NAS CODE (Originally written in 1964…revised in1992) Cleanliness Requirements of Parts Used in Hydraulic Systems (available from Global Engineering Documents)														
Particle Size Range (microns)	MAXIMUM NUMBER OF PARTICLES PER 100 MILLILITRES (COUNTS/100 ML)													
	OO	O	1	2	3	4	5	6	7	8	9	10	11	12
5 to 15	125	250	500	1,000	2,000	4,000	8,000	16,000	32,000	64,000	128,000	256,000	512,000	1,024,000
15 to 25	22	44	89	178	356	712	1,425	2,850	5,700	11,400	22,800	45,600	91,200	182,400
25 to 50	4	8	16	32	63	126	253	506	1,012	2,025	4,050	8,100	16,200	32,400
50 to 100	1	2	3	6	11	22	45	90	180	360	720	1,440	2,880	5,760
>100	0	0	1	1	2	4	8	16	32	64	128	256	512	1,024

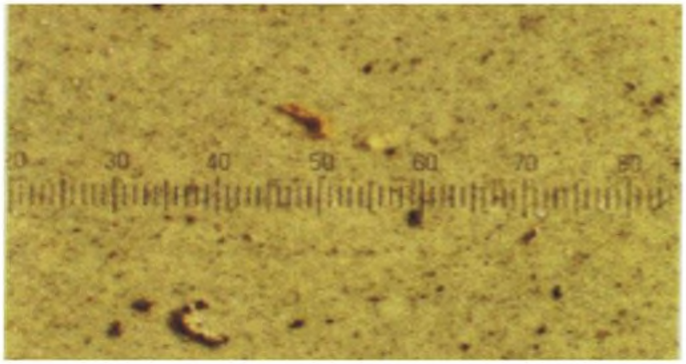
ISO 4406

- ISO 4406 (1999) assigns a cleanliness code in the format X/Y/Z, where:
- X represents the number of particles per mL >4μ
- Y represents the number of particles per mL >6μ
- Z represents the number of particles per mL >14μ
- The X, Y, and Z values correspond to a range of the number of particles per mL of fluid.

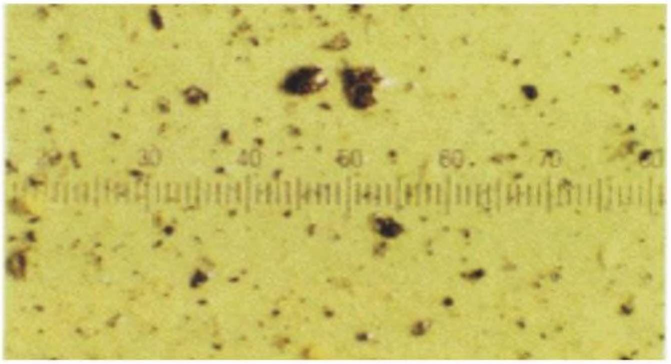
ISO 4406: Hydraulic Fluid Power Solid Contamination Code (1999)		ISO Code
Greater Than	Including	
1,300,000	2,500,000	**28**
640,000	1,300,000	**27**
320,000	640,000	**26**
160,000	320,000	**25**
80,000	160,000	**24**
40,000	80,000	**23**
20,000	40,000	**22**
10,000	20,000	**21**
5,000	10,000	**20**
2,500	5,000	**19**
1,300	2,500	**18**
640	1,300	**17**
320	640	**16**
160	320	**15**
80	160	**14**
40	80	**13**
20	40	**12**
10	20	**11**
5	10	**10**
2.5	5	**9**
1.3	2.5	**8**
0.64	1.3	**7**
0.32	0.64	**6**
0.16	0.32	**5**
0.08	0.16	**4**
0.04	0.08	**3**
0.02	0.04	**2**
0.01	0.02	**1**
0	0.01	**0**

ISO Cleanliness

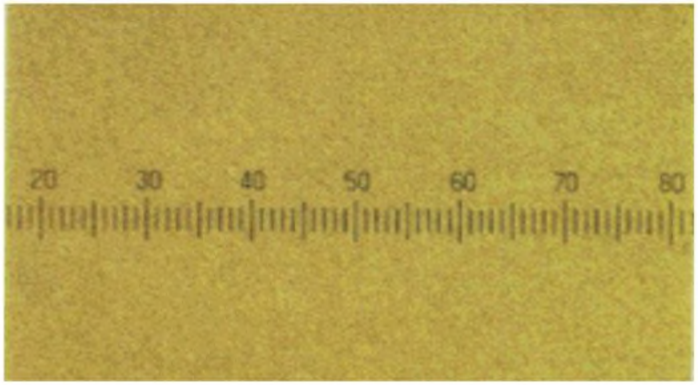
ISO Cleanliness



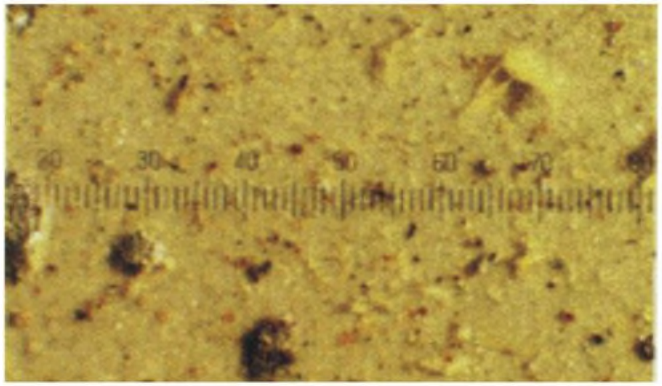
System with Typical Hydraulic Filtration 20/18/16



New Oil from Barrel 22/20/18



System with $\beta 3$ >200 Filtration 14/13/11



New System with Built-in Contaminants 23/22/20

Courtesy: Noria

Equipment Life Extension

- Noria produced a chart of expected life extension for various types of equipment based on reduction in particle count.
- Eaton, Vickers, John Deere, and others have produced charts for their equipment.

EATON

Table I: Hydraulic Systems: Required New Machine Cleanliness

Current Machine Cleanliness (ISO)	Target	Target	Target	Target
28/26/23	25/23/21	25/22/19	23/21/18	22/20/17
27/25/22	25/23/19	23/21/18	22/20/17	21/19/156
26/24/21	**23/21/18**	22/20/17	21/19/16	21/19/15
25/23/20	**22/20/17**	21/19/ 16	20/18/15	19/17/14
25/22/19	**21/19/16**	20/18 /15	19/17/14	18/16/13
23/21/18	**20/18/15**	19/17/14	18/16/13	17/15/12
22/20/17	**19/17/14**	18/16/13	17/15/12	16/14/11
21/19/16	**18/16/13**	17/15/12	16/14/11	15/13/10
20/18/15	**17/15/12**	16/14/11	15/13/10	14/12/9
19/17/14	**16/14/11**	15/13/10	14/12/9	14/12/8
18/16/13	15/13/10	14/12/9	13/11/8	N/A
17/15/12	14/12/9	13/11/8	N/A	N/A
16/14/11	13/11/8	N/A	N/A	N/A
15/13/10	13/11/8	N/A	N/A	N/A
14/12/9	13/11/8	N/A	N/A	N/A
Life Extension Factor	**2X**	**3X**	**4X**	**5X**

Equipment Life Extension

Estimated Life Extension Table

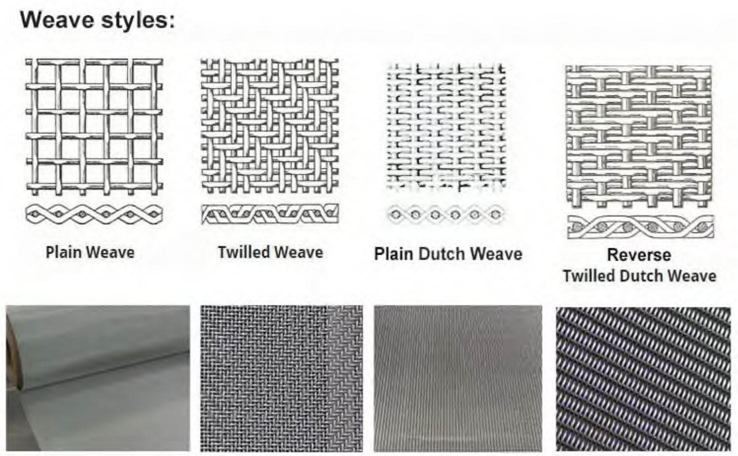
Existing Machine Cleanliness (ISO Code)	Targeted Cleanliness Level (ISO Code)																					
	20/17		19/16		18/15		17/14		16/13		15/12		14/11		13/10		12/9		11/8		10/7	
26/23	5	3	7	3.5	9	4	>10	5	>10	6	>10	7.5	>10	9	>10	>10	>10	>10	>10	>10	>10	>10
	4	2.5	4.5	3	6	3.5	6.5	4	7.5	5	8.5	6.5	10	7	>10	9	>10	10	>10	>10	>10	>10
25/22	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	7	>10	9	>10	>10	>10	>10	>10	>10
	3	2	3.5	2.5	4.5	3	5	3.5	6.5	4	8	5	9	6	10	7.5	>10	9	>10	>10	>10	>10
24/21	3	2	4	2.5	6	3	7	4	9	5	>10	6	>10	7	>10	8	>10	10	>10	>10	>10	>10
	2.5	1.5	3	2	4	2.5	5	3	6.5	4	7.5	5	8.5	6	9.5	7	>10	8	>10	10	>10	>10
23/20	2	1.5	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	6	>10	8	>10	9	>10	>10
	1.7	1.3	2.3	1.5	3	2	3.7	2.5	5	3	6	3.5	7	4	8	5	10	6.5	>10	8.5	>10	10
22/19	1.6	1.3	2	1.6	3	2	4	2.5	5	3	7	3.5	8	4	>10	5	>10	6	>10	7	>10	>10
	1.4	1.1	1.8	1.3	2.3	1.7	3	2	3.5	2.5	4.5	3	5.5	3.5	7	4	8	5	10	5.5	>10	8.5
21/18	1.3	1.2	1.5	1.5	2	1.7	3	2	4	2.5	5	3	7	3.5	9	4	>10	5	>10	7	>10	10
	1.2	1.1	1.5	1.3	1.8	1.4	2.2	1.6	3	2	3.5	2.5	4.5	3	5	3.5	7	4	9	5.5	10	8
20/17			1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	5	>10	7	>10	9
			1.2	1.05	1.5	1.3	1.8	1.4	2.3	1.7	3	2	3.5	2.5	5	3	6	4	8	5.5	10	7
19/16					1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4	9	6	>10	8
					1.2	1.1	1.5	1.3	1.8	1.5	2.2	1.7	3	2	3.5	2.5	5	3.5	7	4.5	9	6
18/15							1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	5	3	7	4.5	>10	6
							1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	3.5	2.5	5.5	3.7	8	5
17/14									1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5	6	3	8	5
									1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.7	3	2	4	2.5	6	3.5
16/13											1.3	1.2	1.6	1.5	2	1.7	3	2	4	3.5	6	4
											1.2	1.1	1.5	1.3	1.8	1.5	2.3	1.8	3.7	3	4.5	3.5
15/12													1.3	1.2	1.6	1.5	2	1.7	3	2	4	2.5
													1.2	1.1	1.5	1.4	1.8	1.5	2.3	1.8	3	2.2
14/11															1.3	1.3	1.6	1.6	2	1.8	3	2
															1.3	1.2	1.6	1.4	1.9	1.5	2.3	1.8
13/10																	1.4	1.2	1.8	1.5	2.5	1.8
																	1.2	1.1	1.6	1.3	2	1.6

Hydraulic and Diesel Engines	Rolling Element Bearings
Journal Bearings and Turbo Machinery	Gear Boxes and Other

Courtesy: Noria

Filtration Basics

- Strainers are large-opening filters that are typically used to protect fluid handling equipment (pumps). Wire cloth of various mesh size and weave design is used to prevent the entry of large particles and debris that could damage the system circulation pump.
- Bag filters can remove large amounts relatively large particles. Often made of cellulose fiber.
- Cartridge filters can provide excellent cleanliness results.
- Filter performance is dependent on rated pore size, beta ratio, and dirt holding capacity.



Filtration Basics

- The filter pore size rating is the size at which the manufacturer determines the efficiency of the filter element. Most filters can be rated at multiple sizes with differing efficiencies. The rating depends on the type of media, depth of the media, size of the media fibers, and overall construction of the filter element.
- Beta (β) ratio is defined as the number of particles of a given size upstream of the filter divided by the number of particles of the same size downstream of the filter. For example, if there are 50,000 10μ particles upstream and 50 10μ particles downstream, the β ratio is 50,000/50 = 1000. The filter efficiency at 10μ is calculated as (1-(1/β))*100 = 99.9%

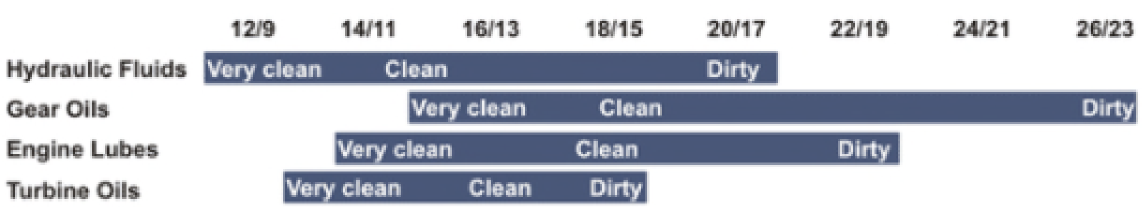
Beta Ratio	Efficiency
1.5	33.3
2	50
5	80
10	90
20	95
75	98.7
100	99
200	99.5
1000	99.9

Filtration Basics

- Dirt holding capacity is the amount of dirt a filter element can hold before it is blinded off or the pressure drop across it becomes excessively high. Dirt holding capacity is affected by the quantity, size, shape, and arrangement of the pores in the filter, and by the type and arrangement of the media or filter design. Larger diameter filters have greater dirt holding capacity. In general, when the diameter is doubled, the dirt holding capacity increases by a factor of 3.

Cleanliness Requirements for Various Applications

- Many lubricant applications have cleanliness requirements, from bearings to gears to hydraulic systems. Hydraulics have some of the most demanding requirements due to the tight clearances and high pressures involved. Some examples of the recommended cleanliness for hydraulic applications follow.



Courtesy: Noria

Machine/element	ISO Target
Roller bearing	16/14/12
Journal bearing	17/15/12
Industrial gearbox	17/15/12
Mobile gearbox	17/16/13
Diesel engine	17/16/13
Steam turbine	18/15/12
Paper machine	19/16/13

Courtesy: Lube-Tech

Cleanliness Requirements for Hydraulic Applications

	Low/Medium Pressure Under 2000 psi (moderate conditions)		High Pressure 2000 to 2999 psi (low/medium with severe conditions)		Very High Pressure 3000 psi and over (high pressure with severe conditions)	
	ISO Target Levels	Filtration Rating ($\beta_{x(c)} \geq 1000$)	ISO Target Levels	Filtration Rating ($\beta_{x(c)} \geq 1000$)	ISO Target Levels	Filtration Rating ($\beta_{x(c)} \geq 1000$)
Pumps						
Fixed Gear or Fixed Vane	20/18/15	22	19/17/14	10	18/16/13	7
Fixed Piston	19/17/14	10	18/16/13	7	17/15/12	7
Variable Vane	18/16/13	7	17/15/12	7	N/A	N/A
Variable Piston	18/16/13	7	17/15/12	7	16/14/11	5
Valves						
Check Valves	20/18/15	22	20/18/15	22	19/17/14	10
Directional (solenoid)	20/18/15	22	19/17/14	10	18/16/13	7
Standard Flow Control	20/18/15	22	19/17/14	10	18/16/13	7
Cartridge Valve	19/17/14	10	18/16/13	7	17/15/12	7
Proportional Valve	17/15/12	7	17/15/12	7	16/14/11	5
Servo Valve	16/14/11	5	16/14/11	5	15/13/10	5
Actuators						
Cylinders, Vane Motors, Gear Motors	20/18/15	22	19/17/14	10	18/16/13	7
Piston Motors, Swash Plate Motors	19/17/14	10	18/16/13	7	17/15/12	7
Hydrostatic Drives	16/15/12	5	16/14/11	5	15/13/10	5
Test Stands	15/13/10	5	15/13/10	5	15/13/10	5
Bearings						
Journal Bearings	17/15/12	7	N/A	N/A	N/A	N/A
Industrial Gearboxes	19/16/13	12	N/A	N/A	N/A	N/A
Ball Bearings	15/13/10	5	N/A	N/A	N/A	N/A
Roller Bearings	16/14/11	5	N/A	N/A	N/A	N/A

Courtesy: Valin

Cleanliness Requirements – Hydraulic Pumps

	Pressure, PSI		
Pump Type	**<2000**	**2000 - 3000**	**>3000**
Fixed gear	20/18/15	19/17/15	18/16/13
Fixed vane	20/18/15	19/17/14	18/16/13
Fixed piston	19/17/15	18/16/14	17/15/13
Variable vane	18/16/14	17/15/13	---
Variable piston	18/16/14	17/15/13	16/14/12

Cleanliness Requirements – Hydraulic Valves

		Pressure, PSI	
Valve Type		**2000**	**>3000**
Directional (Solenoid)		20/18/15	19/17/14
Pressure control (modulating)		19/17/14	18/16/13
Flow control (standard)		19/17/14	19/17/14
Check		20/18/15	20/18/15
Cartridge (screw-in)		18/16/13	17/15/12
Cartridge (slip-in)		20/18/15	19/17/14
Proportional directional (throttle)		18/16/13	17/15/12
Proportional pressure control		18/16/13	17/15/12
Proportional cartridge		18/16/13	17/15/12
Servo		16/14/11	15/13/10

Cleanliness Requirements – Hydraulic Actuators

	Pressure, PSI		
Actuator Type	**1000**	**2000**	**>3000**
Cylinder	20/18/15	20/18/15	20/18/15
Vane motor	20/18/15	19/17/14	18/16/13
Axial piston motor	19/17/14	18/16/13	17/15/12
Gear motor	21/19/17	20/18/15	19/17/14
Radial piston motor	20/18/14	19/17/13	18/16/13

Questions

- Please post your questions using the Q&A function.

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