Guide to Contamination Standards

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Introduction

This guidebook is aimed at engineers, technicians and quality control personnel involved in contamination control. Its purpose is to make available accepted and widely-used cleanliness specification levels for liquid samples.

The tables in this guide allow users of automatic portable particle counters to see the relationship between raw particle counts at various sizes and the reporting code numbers of various contamination standards.

A NOTE ON THE FIGURES USED

Note that some of the table entries are defined as **cumulative** counts (e.g. "> 6µm") and others are defined as **differential** counts (e.g. 6–14µm").

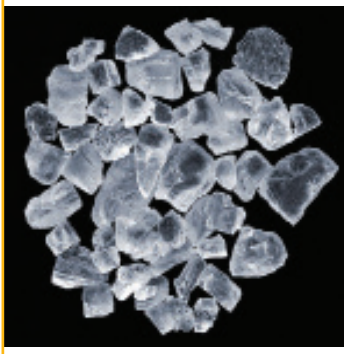
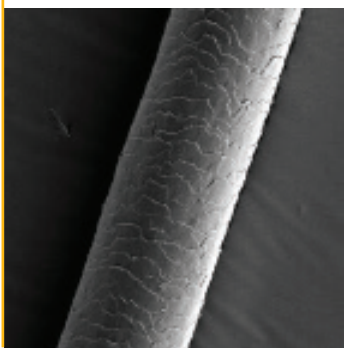
Instances of particle sizes given as "**µm**" refer to ACFTD (i.e. Air Cleaner Fine Test Dust) distributions.
Instances of particle sizes given as "**µm(c)**" refer to MTD (i.e. ISO Medium Test Dust) distributions.

All standards are in counts per volume, and provide easy methods for converting particle counts into limits that are simple to interpret. By noting the requirements of the standard, particle counts can be accurately converted to contamination levels.

Contamination basics

Solid contaminants in fluid systems vary in size, shape, form and quantity. The most damaging contaminants in hydraulic systems are normally between 6 and 14 microns, and therefore cannot be seen by the naked eye.

The table below gives an indication of the relative sizes of common objects.

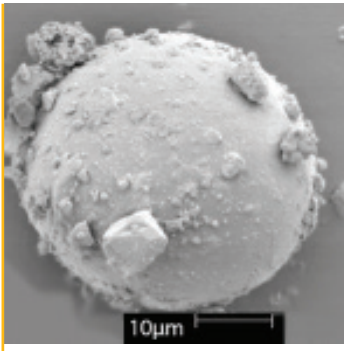
Object	Typical Size	Image
Grain of table salt	100 µm	
Diameter of human hair	70 µm	

Limit of human visibility (naked eye)

40 µm

Milled flour

25 µm

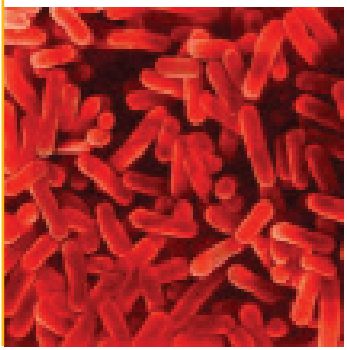


Red blood cells

8 µm

Bacteria

2 µm



NOTE: One micron (µm) equals one thousandth of a millimetre (1µm = 0.001mm).

ISO 4406:1999 codes (hydraulic fluid contamination)

ISO standard 4406:1999 provides a way of summarising the distribution of contaminants in a fluid by counting the particles per 100ml sample of hydraulic fluid: the figures are cumulative. To make the numbers less cumbersome, they are converted to number codes, as in the following table.

Each code measures a "channel" of representative particle sizes that are particularly associated with wear and damage in hydraulic systems: these are 4µm(c), 6µm(c) and 14µm(c).

For example, 700 000 particles larger than 4µm(c) corresponds to ISO 20 (as 700 000 is more than 500 000 but fewer than 1 000 000). In the same way, 140 000 particles larger than 6µm(c) corresponds to ISO 18; and 7 000 particles larger than 14µm(c) corresponds to ISO 13. So this fluid would be reported as 20 / 18 / 13.

When the raw data in one of the size ranges results in a particle count of fewer than 20 particles, the scale number for that size range is labelled with the symbol '>'.

ISO code number	Number of particles per 100ml sample	
	More than	Up to and including
24	8 000 000	16 000 000
23	4 000 000	8 000 000
22	2 000 000	4 000 000
21	1 000 000	2 000 000
20	500 000	1 000 000
19	250 000	500 000
18	130 000	250 000
17	64 000	130 000
16	32 000	64 000
15	16 000	32 000
14	8 000	16 000
13	4 000	8 000
12	2 000	4 000
11	1 000	2 000
10	500	1 000
9	250	500
8	130	250
7	64	130
6	32	64
5	16	32
4	8	16
3	4	8
2	2	4
1	1	2

Suggested acceptable contamination levels

ISO code numbers	Type of system	Typical components	Sensitivity
23 / 21 / 17	Low pressure systems with large clearances	Ram pumps	Low
20 / 18 / 15	Typical cleanliness of new hydraulic oil straight from the manufacturer. Low pressure heavy industrial systems or applications where long-life is not critical	Flow control valves Cylinders	Average
19 / 17 / 14	General machinery and mobile systems medium pressure, medium capacity	Gear pumps/motors	Important
18 / 16 / 13	World Wide Fuel Charter cleanliness standard for diesel fuel delivered from the filling station nozzle. High quality reliable systems General machine requirements	Valve and piston pumps/ motors Directional and pressure control valves	Very important
17 / 15 / 12	Highly sophisticated systems and hydrostatic transmissions	Proportional valves	Critical
16 / 14 / 11	Performance servo and high pressure long-life systems e.g. Aircraft machine tools, etc.	Industrial servo valves	Critical
15 / 13 / 09	Silt sensitive control system with very high reliability Laboratory or aerospace	High performance servo valves	Super critical

NOTE: The three figures of the ISO code numbers represent ISO level contamination grades for particles of >4µm(c), >6µm(c) and >14µm(c) respectively.

ISO codes (fuel contamination)

ISO standard 4406:1999 is used to measure contamination in fuel, as well as in hydraulic systems (see page 6).The only difference is that particle counts are usually expressed as per millilitre, rather than per 100ml, so the raw counts are generally 100 times lower.

ISO code no.	Number of particles per ml: More than	Number of particles per ml: Up to and including
22	20 000	40 000
21	10 000	20 000
20	5 000	10 000
19	2 500	5 000
18	1 300	2 500
17	640	1300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
09	2.5	5
08	1.3	2.5
07	0.64	1.3

Typical reporting: particle sizes

Hydraulic	ISO MTD	4µ(c)	6µ(c)	14µ(c)	21µ(c)	38µ(c)	70µ(c)
Fluid	ACFTD	2µ	5µ 1	5µ	25µ	50µ	–
Fuel	ISO MTD	4µ(c)	6µ(c)	14µ(c)	21µ(c)	25µ(c)	30µ(c)

Industry conventionally reports raw particle counts as per 100ml for hydraulic fluids, and per ml for fuel, though this is not part of any standard.

NAS 1638 table

The NAS 1638 cleanliness standard was developed for aerospace components in the US and is still widely used for industrial and aerospace fluid power applications and in the UK North Sea industries.

The figures are differential counts, and the NAS class is usually reported as a single figure representing the maximum allowed particle counts (i.e. worst case) for designated particle size ranges.

	Size range	5–15 µm	15–25 µm	25–50 µm	50–100 µm	>100 µm
NAS classes (based on maximum contamination limits, particles per 100ml)	00	125	22	4	1	0
	0	250	44	8	2	0
	1	500	89	16	3	1
	2	1000	178	32	6	1
	3	2000	356	63	11	2
	4	4000	712	126	22	4
	5	8000	1425	253	45	8
	6	16 000	2850	506	90	16
	7	32000	5700	1012	180	32
	8	64000	11400	2025	360	64
	9	128000	22800	4050	720	128
	10	256000	45600	8100	1440	256
	11	512000	91000	16200	2880	512
	12	1024000	182400	32400	5760	1024

SAE AS4059 rev E table

Note that this standard is technically identical to ISO 11218.

MTD
ISO11171 (Calibration or optical microscope count – particle size based on projected area equivalent diameter)

ACFTD
ISO4402 (Calibration or optical microscope count – particle size based on longest dimension)

Maximum contamination limits (particles per ml)						
MTD	>4µm(c)	>6µm(c)	>14µm(c)	>21µm(c)	>38µm(c)	>70µm(c
ACFTD	>2µm	>5µm	>15µm	>25µm	>50µm	>100µm
Size code	A	B	C	D	E	F
000	195	76	14	3	1	0
00	390	152	27	5	1	0
0	780	304	54	10	2	0
1	1560	609	109	20	4	1
2	3120	1220	217	39	7	1
3	6250	2430	432	76	13	2
4	12500	4860	864	152	26	4
5	25000	9730	1730	306	53	8
6	50000	19500	3460	612	106	18
7	100000	38900	6920	1 220	212	32
8	200000	77900	13900	2 450	424	64
9	400000	156000	27700	4 900	848	128
10	800000	311000	55400	9 800	1700	256
11	160000	623000	111000	19 600	3390	512
12	320000	1250000	222000	39 200	6780	1024

GOST 17216-2001 table

The GOST standard is developed by the Technical Committee of Standardization TK 184 "Ensuring Industrial Cleanliness" introduced by the Government of Russia.

Adopted by the Inter-governmental Committee of Standardization Metrology and Certification.

(Protocol No.19 dated 24 May 2001).

	Size range	5–10µm	10–25µm	25–50µm	50–100µm	100–200µm
Particle contamination level by class (particles per 100ml)	00	8	4	1	0	0
	0	16	8	2	0	0
	1	32	16	3	0	0
	2	63	32	4	1	0
	3	125	63	8	2	0
	4	250	125	12	3	0
	5	500	250	25	4	1
	6	1000	500	50	6	2
	7	2000	1000	100	12	4
	8	4000	2000	200	5	6
	9	8000	4000	400	50	12
	10	16000	8000	800	100	25
	11	31500	16000	1600	200	50
	12	63000	31500	3150	400	100
	13	–	63000	6300	800	200
	14	–	125000	12500	1600	400
	15	–	–	25000	3150	800
	16	–	–	50000	6300	1600
	17	–	–	–	125000	3150

NAV AIR 10-1A17 table

The Navy Standard for Hydraulic Fluids used for aircraft hydraulic systems is defined in the Aviation Hydraulics Manual (1989), Table 2-1, Navy Standard for Particulate Cleanliness.

NAVY STANDARD FOR HYDRAULIC FLUIDS – USED FOR AIRCRAFT HYDRAULIC SYSTEMS

Particle Contamination Level by Class							
Particle size in µm	0	1	2	3	4	5	6
	Number of particles per 100ml						
5–10	2700	4600	9700	24000	32000	87000	128000
10–25	670	1340	2680	5360	10700	21400	42000
25–50	93	210	380	780	1510	3150	6500
50–100	16	28	56	110	225	430	1000
>100	1	3	5	11	21	41	92

ISO/NAS/SAE code comparison table

The comparisons relate to particle count data only. To conform to any particular standard, reference should be made to the recommended experimental procedure.

ISO/DIS 4406 BS 5540/4 codes	Defence Std. 05/42		NAS 1638	SAE 749
	Table A	Table B		
13 / 11 / 08			2	
14 / 12 / 09			3	0
15 / 13 / 10			4	1
16 / 14 / 09		400F		
16 / 14 / 11			5	2
17 / 15 / 09	400			
17 / 15 / 10		800F		
17 / 15 / 12			6	3
18 / 16 / 10	800			
18 / 16 / 11		1300F		
18 / 16 / 13			7	4
19 / 17 / 11	1300	2000		
19 / 17 / 14			8	5
20 / 18 / 12	2000			
20 / 18 / 13		4400F		
20 / 18 / 15			9	6
21 / 19 / 13	4400	6300F		
21 / 19 / 16			10	
22 / 20 / 13	6300			
22 / 20 / 17			11	
23 / 21 / 14		15000		
23 / 21 / 18			12	
24 / 22 / 15	21000			
25 / 23 / 17	100000			

PPM Conversion table

Percent contamination vs. PPM (parts per million)	
Percent	PPM
100%	1 000 000
10%	100 000
1%	10 000
0.1%	1 000
0.01%	100
0.001%	10

Volume	
1 litre =	1 000 ml
1 PPM =	1 µl in 1 litre

Example 1	
400 PPM in 1 litre	= 400 µl

Example 2

A reading of 250 PPM equates to a quantity of absorbed water in a 400 ltr. capacity system of 0.1 litre.

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icountLCM20 portable particle counter

- 2-minute test procedure.
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- Data entry, data graphing and integral printer
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- Cost effective, portable condition monitoring for hydraulic oil and fuel systems.
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- Proven laser detection technology.
- A self contained, field-use oil sampler with on-board battery
- Delivers precise, repeatable particulate results down to 4 microns (c).

icountBS2 bottle sampler

- icountBS2 provides quick sample bottle analysis with variable test time options from 15 seconds and volume capacities from 10ml.
- Repeatable and re-producible results performance, calibration carried out to ISO11171 via ISO11943 principles.
- Design concept allows for portability with AC and rechargeable battery power options built-in.
- Sample tube self-cleaning sleeve minimizing contamination crossover.
- CE Marked.

icountPD particle detector

- icountPD provides online and independent monitoring of system contamination trends.
- Laser diode light obscuration technology for repeatable results.
- Calibration to approved, on-line methods.
- Early warning LED or digital display indicators for low, medium and high contamination levels.
- Moisture RH% indicator option for real time water ingress awareness before saturation damage occurs.
- Fully PC/PLC integration technology such as:
  – RS232, 0-5V, 4-20mA, CANBUS (J1939).

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Parker Hannifin Manufacturing (UK) Ltd.
Hydraulic Filter Division Europe
conmoninfo@parker.com
www.parker.com/hfde

FDCB805UK 02/2012