ISOCLEAN® CERTIFIED LUBRICANTS

Chevron

TECHNICAL BULLETIN

LUBRICANT CLEANLINESS CLASSIFICATION SYSTEMS EXPLAINED

Over the past 60 years, a variety of lubricant cleanliness standards have been created with the goal to help end users measure and manage particle contamination for various components utilized in their industry. The justification is a direct correlation to fluid contamination and component wear. These systems were derived to measure the size and distribution of contamination in the lubricant in use as many of the particle contaminants are smaller than what can be detected by the human eye. Note, the lower limit of what a human eye can visibly detect is 40 µm (micron) and a significant amount of wear occurs from particle contamination that is less than 15 µm.

Therefore, by achieving an optimal fluid cleanliness level, machinery life will be prolonged. While there are more classifications in the world than what are described herein, I am focused on three prevalent classifications for the North America Region that have been used to define fluid cleanliness:

1. National Aerospace Standard (NAS) 1638
2. SAE Aerospace (AS) 4059
3. International Standards Organization (ISO) 4406

1. NAS 1638

Table 1

NAS 1638					
Maximum Particles/100 mL in Specified Size Range (µm)					
Class	5-15 µm	15-25 µm	25-50 µm	50-100 µm	>100 µm
00	125	22	4	1	0
0	250	44	8	2	0
1	500	89	16	3	1
2	1,000	178	32	6	1
3	2,000	356	63	11	2
4	4,000	712	126	22	4
5	8,000	1,425	253	45	8
6	16,000	3,850	506	90	16
7	32,000	5,700	1,012	180	32
8	64,000	11,400	2,025	360	64
9	128,000	22,800	4,050	720	128
10	256,000	45,600	8,100	1,440	256
11	512,000	91,200	16,200	2,880	512
12	1,024,000	182,400	32,400	5,760	1,024

The NAS 1638 [1] is a legacy system for aerospace and industrial fluid power applications. This system was conceived in the 1960s to help the U.S. Aerospace industry measure and control particle contamination delivered in aircraft hydraulic components. It assigns a cleanliness class based on either a particle count or weight. Classes 00 – 12 describe a maximum number of particles in 5 size groupings (Table 1):

- 5 to 15 µm
- 15 to 25 µm
- 25 to 50 µm
- 50 to 100 µm
- > 100 µm

NAS 1638 employs differential counts, the number of particles within a given range. Note, a change in particle count classification where the number moves one Class higher means the level of contamination has doubled.

Table 2

Weight of Particles for 100 mL Based on New Weight (ARP785) (Total Weight Minus Extraneous Weight, i.e. Tare, Etc.)									
Class	100	101	102	103	104	105	106	107	108
Weight (mg)	0.02	0.05	0.10	0.30	0.50	0.70	1.0	2.0	4.0

a) Classes 100, 101 and 102 will require samples larger than 100 mL
b) A correlation between Table 1 and Table 2 is neither expressed or implied

NAS 1638 Classes 100 – 108 prescribe a maximum particulate weight per 100 mLs (Table 2).

Though contemporary cleanliness specifications most commonly rely on particle counts, some standards (i.e. MilSpec MIL-PRF-17331L) continue to rely on gravimetric methods.

Over a period of time, it was found the NAS classification system was problematic for real life implementation, such as trending the data. For more information on why NAS 1638 became irrelevant, read Lubrication's article, "What happened to NAS 1638," Mike Day, Pall Corporation.[2] Additionally, the NAS system has not been used for components designed after May 2001.

2. AS 4059

The SAE Aerospace (AS) 4059 [3] cleanliness classification for hydraulic fluids was developed in 1988 to modernize the legacy NAS 1638 classification system. This updated classification overcame many of the constraints for the NAS 1638 system such as: improving repeatability and reproducibility, incorporating a cleaner class, allowing flexibility with cleanliness specifications, providing application guidance and accommodating for the newly developed automatic particle counters (APCs) which utilize a different particle sizing methodology than microscopy methods to quantify contamination. Note, AS4059 was adopted as ISO 11218 (published in 2017).

SAE AS4059 Rev F allows for two methodologies to quantify contamination: differential counts like NAS 1638 or cumulative counts like ISO 4406 (described below). A differential total shows the counts which are at least that size in diameter and up to, but not including, the next size up in particle contamination; whereas a cumulative total shows the number of particles that were found at that size and greater.

When employing differential counts, AS4059F considers particles in 5 size ranges for particle limits for Classes 00 through 12. These contamination Classes and particle count limits are identical to NAS 1638. For example, the AS4059 Class 8 is the same as the NAS 1638 Class 8. When employing cumulative counts, AS4059F considers particles in 6 size ranges defined by classes 000 through 12. The size range of particles counted for both differential and cumulative are determined on the measurement method of either:

1. Microscope particles based on longest dimension as measured per ISO 4407 (or AS598) or
2. APC calibrated per ISO 11171 [4] or an optical electron microscope with image analysis software based on projected equivalent diameter

Table 3 features the cumulative quantification method (a table showing the differential method is not included in this section). This table shows the relationship between particle size, count, and contamination code. The combined list of particle contamination levels can be reported as a contamination code. Note, the contamination class is equal to the highest contamination level determined among all the given particle size ranges.

Table 3

AS4059F - Cumulative Particle Count Table						
Maximum Particles/100 mL in Specified Size Range (µm)						
ISO 4407 or Optical Microscope*	>2 µm	>5 µm	>15 µm	>25 µm	>50 µm	>70 µm
ISO 11171 or Electron Microscope**	>4 µm (c)	>6 µm (c)	>14 µm (c)	>21 µm (c)	>38 µm (c)	>100 µm (c)
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	1,560	609	109	20	4	1
2	3,120	1,220	217	39	7	1
3	6,520	2,430	432	76	13	2
4	12,500	4,860	864	152	26	4
5	25,000	9,730	1,730	306	53	8
6	50,000	19,500	3,460	612	106	18
7	100,000	38,900	6,920	1,220	212	32
8	200,000	77,900	13,900	2,450	424	64
9	400,000	156,000	27,700	4,900	848	128
10	800,000	311,000	55,400	9,800	1,700	256
11	1,600,000	623,000	111,000	19,600	3,390	512
12	3,200,000	1,250,000	222,000	39,200	6,780	1,024

* Particle size based upon longest dimension as measured per ISO 4407 or AS596.
** Particle size based upon projected area equivalent diameter.

This cumulative particle contamination can be reported in a variety of ways: [5]

1. Specify single sizes, such as 5B, which means that only >5 µm/>6 µm (c) is subject to that spec
2. Specify for specific particle sizes such as 7B/6C/5D
3. Specify for a complete size range such as 5 A through F (written as Class 8 A-F)

When reporting AS4059F cleanliness using cumulative particle counts (cpc) in accordance with Table 3, the contamination code/class should be preceded by "cpc" (Table 4). Using the AS4059 can be cumbersome as reporting the specifics is crucial and sometimes gets lost in translation.

Table 4

Reporting Example for AS4059F - Cumulative Particle Count Table with APC						
Size in µm	>4 µm (c)	>6 µm (c)	>14 µm (c)	>21 µm (c)	>38 µm (c)	>100 µm (c)
Particle count per 100 mL	382 000	127 000	13 300	4140	224	52
Contamination Level	9	9	8	9	8	8
Contamination Code	AS4059 Contamination Code cpc [9/9/8/9/8/8]					
AS4059 Contamination Class	AS4059 cpc Class 9					

3. ISO 4406

The ISO 4406 [6] Cleanliness Code is the newest classification which was originally published in 1987 and revised in 2017. The purpose of this standard is to simplify the reporting of particle count data by converting the numbers into a broader class or codes where an increase in 1 code represents double the contamination. This standard uses cumulative counting to report particulate contamination based on an optical APC projected area equivalent diameter, which is different than a contaminant measured by a microscope.

Over time, it has become widely accepted in a variety of industries that the smallest particles (those below size 15 micron) cause the most damage to machinery and components, which makes this system both user friendly and relevant today.

Table 5

ISO 4406		
ISO Cleanliness Code	**More than (p/1 mL)**	**Up to & including (p/1 mL)**
24	80,000	160,000
23	40,000	80,000
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	1,300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5

ISO 4406 groups contamination into three particle size ranges: [6]

- ≥4 µm (XX)
- ≥6 µm (YY)
- ≥14 µm (ZZ)

It is written as a three-digit code: XX/YY/ZZ. The numbers in the code correlate to a table that specifies how many of that contaminate particle size are present per one milliliter (mL) of fluid. It's worth noting that the other two classification systems count particles per/100 mL.

For example, a code written as 20/17/13 (see Table 5) would mean there are between 5,000 – 10,000 particles of a size 4 µm and greater present, 640 to 1,300 particles size 6 µm and greater and finally between 40 to 80 particles size 14 µm and greater. Essentially, a laboratory counts the contaminate particles and evaluates the distribution classification that in turn provides the respective ISO 4406 code to indicate the level of contamination present.

It is important to note that for every additional (1) code higher, the contamination level doubles. Conversely, every additional (1) code lower means that the contamination levels are cut in half. This means that achieving or not exceeding OEM/component cleanliness standards by as little as 1 code significantly impacts that component's lifespan. The ISO 4406 classification system has largely been adopted by Original Equipment Manufacturers (OEMs), filtration companies and the lubrication industry. It was developed to standardize to a universally accepted reporting system across the globe.

SUMMARY

There are a variety of measurement standards which have been developed over the years for different industries, applications and geographic regions. In attempt to provide a read across chart for fluid cleanliness from AS4059F to ISO 4406 please see Table 6. The next time you are asked about NAS, AS4059 or ISO cleanliness standards, you will be well equipped to explain classification systems and how to obtain the appropriate cleanliness levels for machinery and components.

Table 6

From AS4059 / NAS 1638 to ISO 4406				
AS4059F [cumulative] Class	AS4059F [differential] NAS 1638 Class	ISO 4406		
		>4	>6	>14
000		8	7	4
00	00	9	8	5
0	0	10	9	6
1	1	11	10	7
2	2	12	11	8
3	3	13	12	9
4	4	14	13	10
5	5	15	14	11
6	6	16	15	12
7	7	17	16	13
8	8	18	17	14
9	9	19	18	15
10	10	20	19	16
11	11	21	20	17
12	12	22	21	18

**This table is a generalized comparison. Each standard prescribes its own size ranges and contamination codes.*

From ISO 4406 to AS4059F [cumulative]			
ISO 4406 Code	AS4059F "A"	AS4059F "B"	AS4059F "C"
0			
1			
2			
3			
4			000
5			00
6			0
7		000	1
8	000	00	2
9	00	0	3
10	0	1	4
11	1	2	5
12	2	3	6
13	3	4	7
14	4	5	8
15	5	6	9
16	6	7	10
17	7	8	11
18	8	9	12
19	9	10	12
20	10	11	12
21	11	12	12
22	12	12	12
23	12	12	12
24	12	12	12
25	12	12	12
26	12	12	12
27	12	12	12
28	12	12	12

**This table is a generalized comparison. Each standard prescribes its own size ranges and contamination codes.*

SOURCES

[1] NAS 1638 "Cleanliness requirements of parts used in Hydraulic systems," Aerospace Industries Association, Arlington, VA, USA, 2011.

[2] Day, Mike, "What Happened to NAS 1638?" Machinery Lubrication, November 2002. https://www.machinerylubrication.com/Read/409/nas-1638

[3] AS4059 Rev. F, "Aerospace Fluid Power - Cleanliness Classification for Hydraulic Fluids," SAE, USA, 1988, Revised 9-2013.

[4] ISO 11171 "Hydraulic fluid power - Calibration of automatic particle counters for liquids," International Organization for Standardization Switzerland, 2016.

[5] Devin, Jarret, "Particle Counts: What They Mean and How to Use Them" Machinery Lubrication, April 2019. https:// www.machinerylubrication.com/Read/31500/use-particle-counts

[6] ISO 4406 "Hydraulic fluid power - Fluids - Method for coding level of contamination by solid particles," International Organization for Standardization, 2018.

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