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AEROSPACE STANDARD

SAE AS4059 | REV. C

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Superseding AS4059B

(R) Aerospace Fluid Power - Cleanliness Classification for Hydraulic Fluids

1. SCOPE:

1.1 This SAE Aerospace Standard (AS) defines cleanliness levels for particulate contamination of hydraulic fluids and includes methods of reporting data relating to the contamination levels. The contamination levels selected are an extension of the widely accepted NAS 1638 cleanliness levels.

1.2 Purpose:

The intent of this standard is to establish the minimum information required to allow valid comparison and interpretation of contamination levels in hydraulic systems that require control of particulate contamination to ensure system performance and reliability.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP598	The Determination of Particulate Contamination in Liquids by the Particle Count Method
ARP785	Aerospace - Procedure for the Determination of Particulate Contamination in Hydraulic Fluids by the Control Filter Gravimetric Procedure
AIR877	Particle Count Data Conversion and Extrapolation
ARP5376	Aerospace - Fluid Systems and Components - Methods, Locations and Criteria for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids

TO PLACE A DOCUMENT ORDER: (724) 776-4970 FAX: (724) 776-0790 SAE WEB ADDRESS: http://www.sae.org

2.2 AIA Publications:

Available from Aerospace Industries Association, 1250 Eye Street, NW, Washington, DC 20005.

NAS 1638 Cleanliness Requirements of Parts Used in Hydraulic Systems (See Appendix A for NAS 1638 Contamination Limits)

2.3 ISO Publications:

Available from International Organization for Standardization, 1 rue de Varembe, 1211 Geneva 20 Switzerland, American National Standards Institute, 11 West 42nd Street, New York, NY 10036-8002 Web address: http://www.ansi.org or from the National Fluid Power Association (NFPA) Telephone (414)-778-3344 Web address: http://www.nfpa.com.

ISO 4402 (1991)	Hydraulic fluid power - Calibration of automatic-count instruments for particles suspended in liquids - Method using classified AC fine test dust
ISO 4406	Hydraulic fluid power - Fluids - Method for coding the level of contamination by solid particles
ISO 11171	Hydraulic fluid power - Calibration of liquid automatic particle counters
ISO 11218	Aerospace - Cleanliness classification for hydraulic fluids
ISO 12103-1	Road vehicles - Test dust for filter evaluation - Part 1: Arizona test dust

3. BACKGROUND:

3.1 Appendix A contains the following information that will help the user understand the requirements of this standard:

a. Comparison of NAS 1638 and AS4059 cleanliness levels
b. Automatic particle counter calibration procedures and their effect on cleanliness classes
c. NAS 1638 cleanliness classes

4. AS4059 CLEANLINESS CLASSES:

4.1 Cleanliness Levels by Particle Size:

Table 1 lists the cleanliness classes established to provide a set of criteria for specifying fluid cleanliness levels. The classes are based on contaminant size, count, and distribution. Because the particle size depends upon the calibration and method of measurement, the sizes have been assigned alpha characters, A, B, C, D, E, and F. Note that the symbol µm(c) is used throughout this document to designate that the particle size was determined using a liquid automatic particle counter calibrated per ISO 11171. The size actually counted will depend upon the calibration method used for the automatic particle counter as identified in Table 1.

TABLE 1 - AS4059 Cleanliness Levels by Particle Count

		Maximum Contamination Limits (particles/100 mL)					
Size, ISO 4402 Calibration, or Optical Microscope Count*		> 1 µm	> 5 µm	> 15 µm	> 25 µm	> 50 µm	> 100 µm
Size, ISO 11171 Calibration or Electron Microscope**		> 4 µm(c)	> 6 µm(c)	> 14 µm(c)	> 21 µm(c)	> 38 µm(c)	> 70 µm(c)
Size Code		**A**	**B**	**C**	**D**	**E**	**F**
CLASSES	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	12,500	4860	864	152	26	4
	5	25,000	9730	1730	306	53	8
	6	50,000	19,500	3460	612	106	16
	7	100,000	38,900	6920	1220	212	32
	8	200,000	77,900	13,900	2450	424	64
	9	400,000	156,000	27,700	4900	848	128
	10	800,000	311,000	55,400	9800	1700	256
	11	1,600,000	623,000	111,000	19,600	3390	512
	12	3,200,000	1,250,000	222,000	39,200	6780	1020

* Particle size based on longest dimension
** Particle size based on projected area equivalent diameter

4.1 (Continued):

To provide versatility, the applicable cleanliness class can be identified in the following ways:

a. Total number of particles larger than a specific size.

Examples:

AS4059 Class 6 (see 4.1.1)
AS4059 Class 6B (see 4.1.1)

b. Designating a class for each size range.

Examples:

AS4059 Class 6B/5C/4D/4E (see 4.1.2)
AS4059 Class 6B/5C/4D/3E/3F (see 4.1.2)

c. Basing the class on the highest class of multiple size ranges (used when NAS 1638 requirements are specified).

Example:

AS4059 Class 6B-F (see 4.1.3)

4.1.1 Classification Based on a Single Size: The NAS 1638 and AS4059 classes are based on a natural distribution of particle sizes. This natural distribution does not really apply for particles in a filtered fluid as used in a hydraulic system. In a filtered fluid, the highest class number will usually be determined by the counts for the smallest particle size of interest. Therefore, AS4059 Revision B and earlier based the class on the smallest particle size of interest since the smallest particle size usually had the highest class number. Class 5B means no more than 9730 particles per 100 mL greater than size B (5 µm for ISO 4402 calibration and 6 µm(c) for ISO 11171 calibration). If these smaller size particles are not of interest, one might require Class 5C which limits the number of particles per 100 mL to 1730 for size C and larger particles.

NOTE: Where an AS4059 class is specified without a size suffix, it means that the counting requirements for size B are to be applied to provide continuity with AS4059 classes for Revision B and earlier.

4.1.2 Designating a Class for Each Size Range: Automatic particle counters can easily count the number of particles in several size ranges. Today, a different class of cleanliness is often desired for each of several size ranges. Requirements can be stated and cleanliness can easily be reported for a number of size ranges. Examples are provided below:

a. 7B/6C/5D/4E/3F is a numeric-alpha representation in which the number designates the cleanliness class and the alphabetical letter designates the particle size range to which the class applies.

b. 7B/6C/5D indicates that the number of particles for each size range do not exceed the following maximum number of particles:

Size B: 38,900 per 100 mL
Size C: 3460 per 100 mL
Size D: 306 per 100 mL

A class may be designated for each size from A through F. See 4.2.1 for guidance regarding use of Classes A and F.

4.1.3 Cleanliness Class Based Upon Multiple Ranges: When this method is used the cleanliness class is determined for multiple size ranges and the highest class in any size range is then used to identify the cleanliness class. This method is included herein to identify requirements based on NAS 1638. However, results are to be reported for each size range as identified in 4.1.2. To designate NAS 1638 Class 6 one would specify: Fluid cleanliness shall meet AS4059 Class 6B-F.

Examples:

a. AS4059 Class 6B-F requires that the particles be counted in all sizes B through F and that the counts for each size shall be less than the maximum permitted per 100 mL for Class 6.

b. AS4059 Class 6B-E is the same as Class 6B-F except that size F particles, for which a more complex counter calibration procedure is required, are not counted (see 4.2.1).

4.2 Specifying Cleanliness Levels:

Cleanliness levels shall be specified by the appropriate class from Table 1 as identified in 4.1.1 through 4.1.3.

4.2.1 Selection of Size Ranges: For Classes 6 and greater, invoking requirements for the smallest size (A) particle is not usually required although most automatic particle counters can handle up to Class 10 without dilution.

Specifying the largest size (F) requires a more complex automatic particle counter calibration procedure and the use of an additional contaminant, spherical latex beads, as identified in ISO 11171.

5. SAMPLING AND ANALYSIS:

5.1 Procedures:

Sampling and analysis of fluid shall be in accordance with ARP5376.

5.1.1 Particle Count Measurement: Particle counts shall be made with an automatic particle counter calibrated per ISO 4402:1991 or ISO 11171. Microscopic particle counts in accordance with ARP598 are acceptable.

6. DETERMINATION AND REPORTING OF CLEANLINESS CLASS:

6.1 AS4059 Cleanliness Data Sheet:

Because sampling, automatic particle counter calibration procedures, and other factors are so important in determining fluid cleanliness, the AS4059 Fluid Cleanliness Data Sheet (DS-1) or equivalent shall be used for each sample.

NOTE: Users have permission to reproduce the data sheet.

6.2 Determination of Cleanliness Class:

The fluid cleanliness classification is determined from Table 1 by the number of particles greater than the applied sizes. In 4.1, three different methods of specifying cleanliness classes are identified. However, for reporting cleanliness classes, the numeric-alpha designation described in 4.1.2 is recommended. This method allows for reporting the cleanliness class for each size range counted.

7. NOTES:

This section contains information of a general or explanatory nature that may be helpful but is not mandatory.

7.1 Transitional Nature of the Document:

AS4059C is written to serve as a transitional document. Activities using counters calibrated per ISO 4402 can use the document as well as those using the new calibration procedure per ISO 11171 based on NIST certified dust. The use of letter designations after the cleanliness class eliminates the need to specifically identify the particle size and calibration procedure since it applies to both the old and new sizes and procedures. It is expected that when AS4059 is next updated, references to the ISO 4402 calibration procedures and sizes will be deleted.

7.2 Counts for Particles Greater than 2 µm in AS4059 Revision B and Earlier:

In earlier revisions, there was an option to count particles larger than 2. See Appendix A for cleanliness classes when particles larger than 2 µm were counted.

7.3 Data Analysis:

AIR877 provides guidance on particle count data conversion and extrapolation for analysis.

7.4 Sampling Errors:

Extracting a fluid sample from a fluid system may generate large particles (size E and larger) which can enter the sample and distort the contamination count. When a sample has an unusually high count in one of the larger size ranges, the sampling device or technique should be considered as a possible cause. By basing cleanliness requirements on the smaller particle sizes, this problem is minimized.

7.5 Dilution:

High levels of contamination may saturate automatic particle counters; therefore, counts greater than 75% of the saturation level of the counter may be suspect. When it is necessary to count particles at a level approaching saturation or greater, it will be necessary to dilute the sample. Care must be exercised when the fluid sample is diluted in order to reduce particle counts below the saturation level of the counter. The dilution fluid must be very clean, Class 0 or better, and must be compatible with the hydraulic fluid and the optical qualities of the fluid used in APC calibration. Dilution presents two major problems. First, any error in dilution will be reflected in total counts. Second, the dilution fluid will contain some particles of various sizes resulting in an erroneous increase in particle counts. With these problems in mind, it is obvious that extremely clean dilution fluid and accurate measurement of the dilution ratio are necessary.

7.6 ISO 4406 Cleanliness Levels:

For industrial hydraulics, cleanliness classifications have been identified and reported in accordance with ISO 4406. Range numbers representing the number of particles larger than 5 and 15 µm with calibration based on ISO 4402 have been used to describe particle counts. With the new ISO 11171 calibration, ISO 4406 identifies counts for particles greater than 4, 6, and 14 µm(c). Thus, the sizes counted per AS4059 will be the same as ISO 4406 except that AS4059 can also be used to identify requirements for larger particles.

NOTE: ISO 4406 counts are per mL while AS4059 counts are per 100 mL.

7.7 The change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document.

7.8 Key Words:

Particle count, particle size, contaminant level, contamination

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APPENDIX A

This Appendix is for information only and does not contain any requirements.

Required Cleanliness: AS4059 Class ____ Based on Size (A, B, or C) ___
NAS 1638 Class _____Other (describe) _____

Sample Identity: Aircraft/Application _____
System/Location _____
Date Taken_____ By _____
Date Analyzed _____ By _____

Sampling Procedure: Bottle ____ Bottle Cleanliness Level _____
On-line ____ Other (describe) _____

Automatic Particle Counter Data: Brand & Model _____
Sensor Model _____
Date Calibrated _____
APC Calibration ___ (ACFTD per ISO 4402)
___ NIST SRM 2806 per ISO 11171
Sensor flow rate _____ mL/min
Volume counted per run _____ mL
Dilution fluid _____

APC Calibration			**Particle Count**	**Volume Counted**	**Dilution Ratio**	**Count per 100 mL**
Size,µm ISO 4402*	**Size, µm(c) ISO 11171**	**SIZE**				
> 1	> 4	A				
> 5	> 6	B				
> 15	> 14	C				
> 25	> 21	D				
> 50	> 38	E				
> 100	> 70	F				

* Also applies to microscope counts per ARP598

Reported Cleanliness Class or Classes: _____

FIGURE A1 - AS4059 Fluid Cleanliness Data Sheet (DS-1)

A.1 COMPARISON OF NAS 1638 AND AS4059 CLEANLINESS LEVELS:

A.1.1 Original NAS 1638 Cleanliness Levels:

NAS 1638, first issued in 1964, has been widely used in the industry for specifying system fluid cleanliness in parts and hydraulic systems. NAS 1638 presented the option of specifying contamination limits by maximum particle counts per 100 mL of fluid or by the weight of contamination per 100 mL of fluid. (See Table A1 for the particle counts for the original NAS 1638 classes.)

TABLE A1 - Original NAS 1638 Maximum Contamination Limits
(Based on a 100 mL Sample Size)

Class	Particle Size Range (Micrometers)*				
	5 to 15	15 to 25	25 to 50	50 to 100	Over 100
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	32,000	5700	1012	180	32
8	64,000	11,400	2025	360	64
9	128,000	22,800	4050	720	128
10	256,000	45,600	8100	1440	256
11	512,000	91,200	16,200	2880	512
12	1,024,000	182,400	32,400	5760	1024

* Same as ARP598.

A.1.2 AS4059 Cleanliness Levels:

This AS uses the same classes for particle count as NAS 1638 but extends the requirements to provide:

a. Cumulative counts greater than a specific size rather than counts within a size range to better reflect the manner in which automatic particle counters perform. NAS 1638 counted particles in the same size ranges as ARP598: 5-15, 15-25, 25-50, 50-100 and >100 µm. When microscope counts per ARP598 are made, fibers with a length greater than 100 µm are reported separately from other particles whose largest dimension is 100 µm.

b. An option to extend particle counts down to 1 µm (ACFTD calibration) or 4 µm(c) (ISO 11711 - NIST calibration). Prior to Revision C, AS4059 provided an option to extend particle counts down to 2 µm (ISO 4402 calibration). While these counts are no longer used, they are provided in Table A2 for historical purposes.

c. A cleaner classification of cleanliness, Class 000, which is not covered in NAS 1638.

d. Versatility to the manner in which cleanliness classes can be specified and reported.

TABLE A2 - AS4059 Revision B and Earlier Classes When Counting Particles Greater Than 2 µm

Class	Maximum Contamination Limits (particles/100 mL)
000	164
00	328
0	656
1	1310
2	2620
3	5250
4	10,500
5	21,000
6	42,000
7	84,000
8	168,000
9	336,000
10	671,000
11	1,340,000
12	2,690,000