SAE INTERNATIONAL

AEROSPACE STANDARD

AS4059™ REV. G

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Superseding AS4059F

Contamination Classification for Hydraulic Fluids

RATIONALE

This document contains a reference to ISO 11500 which requires a statistical check that is not applicable for new clean fluid. This revision introduces a note regarding the non-applicability of ISO 11500 to clarify the verification requirements for new fluids.

1. SCOPE

This SAE Aerospace Standard (AS) defines contamination classes and levels for particulate contamination of hydraulic fluids and includes methods of reporting related data (Appendix A).

2. REFERENCES

2.1 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.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP5376 Methods, Locations, and Criteria for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids

AS598 Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems

2.1.2 AIA Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

NAS1638 Cleanliness Requirements of Parts Used in Hydraulic Systems (inactive for new design and not for use with automatic particle counters)

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/AS4059G/

2.1.3 ISO Publications

Available from International Organization for Standardization, ISO Central Secretariat, 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, Tel: +41 22 749 01 11, www.iso.org.

ISO 4402 (1991) Hydraulic Fluid Power - Calibration of Automatic-Count Instruments for Particles Suspended in Liquids - Method Using Classified AC Fine Test Dust (standard withdrawn and replaced by ISO 11171)

ISO 4407 Hydraulic Fluid Power - Fluid Contamination - Determination of Particulate Contamination by the Counting Method Using an Optical Microscope

ISO 11171 Hydraulic Fluid Power - Calibration of Automatic Particle Counters for Liquids

ISO 11500 Hydraulic Fluid Power - Determination of the Particulate Contamination Level of a Liquid Sample by Automatic Particle Counting Using the Light-Extinction Principle

2.2 Definitions

CONTAMINATION LEVEL: This is the maximum number of counts for a given particle size range.

CONTAMINATION CODE: This is a series of five or six numbers separated by a forward slash used to describe the fluid sample contamination levels at standardized particle size ranges as defined in Tables 1 and 2.

CONTAMINATION CLASS: This is the highest contamination level number within the contamination code.

PARTICLE SIZE: This is the longest dimension of the particle in the case of microscopic counting or the diameter of a circle with an area equal to that of the projected image in the case of automatic particle counting.

3. AS4059 CONTAMINATION LEVELS

3.1 Contamination Levels

Table 1 provides AS4059 contamination levels for differential particle counts, and Table 2 provides AS4059 contamination levels for cumulative particle counts.

These tables list the maximum contamination limits established to provide a set of criteria for specifying the fluid contamination levels, code, and class. The contamination level is based on the particle size range and particle count. Note that the symbol µm(c) is used in Tables 1 and 2 and throughout this document to designate that the particle size was determined using a liquid automatic particle counter calibrated per ISO 11171 or a microscope using image analysis software to calculate the diameter of a circle with the equivalent projected area.

Table 1 - Maximum contamination limits for differential particle counts (particles/100 mL)[3]

Contamination Levels	[1] 5, incl to 15, incl µm	15, excl to 25, incl µm	25, excl to 50, incl µm	50, excl to 100, incl µm	>100 µm
	[2] 6, incl to 14, incl µm(c)	14, excl to 21, incl µm(c)	21,excl to 38, incl µm(c)	38, excl to 70, incl µm(c)	>70 µm(c)
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	16000	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	91200	16200	2880	512
12	1024000	182400	32400	5760	1024

[1] Size range, microscope particle counts, based on the longest dimension as measured per AS598 or ISO 4407.
[2] Size range, automatic particle counters calibrated per ISO 11171 or an optical or electron microscope with image analysis software, based on projected area equivalent diameter.
[3] Contamination classes and particle count limits are identical to NAS1638.

Table 2 - Maximum contamination limits for cumulative particle counts (particles/100 mL)

Contamination Levels	[1] >1 µm	>5 µm	>15 µm	>25 µm	>50 µm	>100 µm
	[2] >4 µm(c)	>6 µm(c)	>14 µm(c)	>21 µm(c)	>38 µm(c)	>70 µm(c)
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	1217	217	39	7	1
3	6250	2432	432	76	13	2
4	12500	4864	864	152	26	4
5	25000	9731	1731	306	53	8
6	50000	19462	3462	612	106	16
7	100000	38924	6924	1224	212	32
8	200000	77849	13849	2449	424	64
9	400000	155698	27698	4898	848	128
10	800000	311396	55396	9796	1696	256
11	1600000	622792	110792	19592	3392	512
12	3200000	1245584	221584	39184	6784	1024

[1] Size range, optical microscope, based on the longest dimension as measured per AS598 or ISO 4407.
[2] Size range, automatic particle counters calibrated per ISO 11171 or an optical or electron microscope with image analysis software, based on projected area equivalent diameter.

3.2 Specifying and Determining the AS4059 Contamination Class

3.2.1 Converting NAS1638 Class Specifications to AS4059 Classes

NAS1638 classes used in current specifications can be converted directly to AS4059 contamination classes. In the simplest form, where NAS1638 Class 6 is currently specified, AS4059 Class 6 applies. Similarly, to designate a fluid contamination class equivalent to NAS1638 Class 6, one would specify: Fluid contamination class shall meet AS4059 Class 6.

3.2.2 Determining the AS4059 Contamination Class Using Differential Particle Counts

This method applies to those currently using NAS1638 classes and desiring to maintain the methods, format, and results equivalent to those specified in NAS1638.

Table 1 applies to acceptance criteria based on differential particle counts and defines the particulate limits for Classes 00 through 12. A contamination level shall be determined for each particle size range. The combined list of contamination levels can be reported as a contamination code. The reported AS4059 contamination class of the sample is equal to the highest contamination level number determined among all the given particle size ranges.

NOTE: The classes and particle count limits in Table 1 are identical to NAS1638. Measurements of particle counts are allowed by the use of an automatic particle counter (calibrated per ISO 11171), or an optical or electron microscope with image analysis software. The size ranges measured and reported shall be determined from Table 1 based on the measurement method.

3.2.2.1 Example Using Microscopic Particle Counts

Table 3 shows example particle counts measured with a microscope based on the longest dimension and the determination of the AS4059 contamination class. The reported contamination class is determined as the maximum contamination level for all size ranges, or in the case, class 9.

Table 3 - Example class determination using microscopic differential particle counts

Size Range in µm	5, incl to 15, incl µm	15, excl to 25, incl µm	25, excl to 50, incl µm	50, excl to 100, incl µm	>100 µm
Particle count per 100 mL	114000	9200	3920	172	52
Contamination Level	9	8	9	7	8
Contamination Code	AS4059 Contamination Code [9/8/9/7/8]				
AS4059 Contamination Class	AS4059 Class 9				

3.2.3 Determining the AS4059 Contamination Class Using Cumulative Particle Counts

This method applies to those using the methods of previous revisions of AS4059 and/or cumulative particle counts. Table 2 applies to acceptance criteria based on cumulative particle counts and defines the particulate limits for levels 000 through 12. A contamination level shall be determined for each particle size range. The combined list of contamination levels can be reported as a contamination code. The reported AS4059 contamination class of the sample is equal to the highest contamination level determined among all the given particle size ranges.

Particle counting by the combination method utilizes both automatic particle counters (APCs) and optical microscopic counting. This method was included because some APCs are not routinely calibrated using the latex method of ISO 11171 for particle sizes above 50 µm(c). Using an APC for counting in the 4 to 38 µm(c) range and a microscope for 70 µm(c) (100 µm) allows such APCs to be used. Of course, this would preclude the particle count from being measured online.

3.2.3.1 Example Using Automatic Particle Counts

Table 4 shows example particle counts measured with an automatic particle counter calibrated per ISO 11171 and the determination of the AS4059 contamination class. The contamination class is determined as the maximum contamination class for all size ranges, or in the case, class 9.

NOTES:

1. The same fluid contaminant level or particle count results may get assigned a different contamination class by Tables 1 and 2.

2. When using cumulative particle counts (cpc) to determine the contamination code or class the series of 6 levels or class shall be preceded by “cpc.”

Table 4 - Example class determination using automatic particle counts

Size Range in µm	>4 µm(c)	>6 µm(c)	>14 µm(c)	>21 µm(c)	>38 µm(c)	>70 µm(c)
Particle count per 100 mL	382000	127000	13300	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					

4. SAMPLING AND ANALYSIS

4.1 Procedures

Sampling and analysis of fluid shall be per ARP5376 or ISO 11500.

NOTES:

1. Sampling errors: Extracting a fluid sample from a fluid system can generate large particles above 50 µm [38 µm(c)] that 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 shall be considered as a possible cause, and additional sampling is recommended.

2. Dilution: High levels of contamination may cause coincidence in automatic particle counters; therefore, counts greater than 75% of the coincidence limit of the counter may be suspect. When it is necessary to count particles at a level approaching the coincidence limit or greater, it will be necessary to dilute the sample. Care must be exercised when the fluid sample is diluted to reduce particle counts below the coincidence limit of the counter. The dilution fluid must be very clean, at least 4 classes cleaner than the fluid being analyzed, and must be compatible with the hydraulic fluid and the optical qualities of the fluid used in automatic particle counter 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.

4.2 Particle Count Measurement

Particle counts shall be made per one of the following methods:

4.2.1 Method A - Automatic Particle Counters

Automatic particle counters (APCs) shall be calibrated per ISO 11171 and particle counting performed per ARP5376 or ISO 11500.

NOTE: New fluid samples may have counts below 20 particles. The minimum of 20 particle counts for ISO 11500 is required for completing a statistical check of the automatic particle counting technique. It is not required for each sample evaluated.

4.2.2 Method B - Optical Microscope

Optical microscopic particle counting shall be conducted per AS598 or ISO 4407. Image analysis software is required for reporting projected area equivalent diameter.

4.2.3 Method C - Combination Method

This method permits the use of automatic particle counters without the need for latex calibration to count 70 µm(c) (100 µm) and larger particles. An optical microscope is used to count particles >100 µm in length. Optical counting of these size large particles or fibers is relatively fast. This method replicates the original NAS1638 requirements for large size particles (see Appendix B).

4.2.4 Method D - Electron Microscope

This is an acceptable method to determine particle count per this specification, although the high equipment cost limits the use of this method to well equipped laboratories. Image analysis software is required for reporting either longest dimension or projected area equivalent diameter.

5. DATA REPORTING

5.1 AS4059 Contamination Data Sheet

Because sampling, automatic particle counter calibration procedures, and other factors are so important in determining fluid contamination, the AS4059 Fluid Contamination Data Sheet (either DS-1 for Table 1, section 3.2.2 or DS-2 for Table 2, section 3.2.3) or equivalent shall be used for each sample (see Appendix A).

6. DOCUMENT INFORMATION

7. NOTES

7.1 Revision Indicator

A 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, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE A-6C1 CONTAMINATION AND FILTRATION COMMITTEE

APPENDIX A - EXAMPLES OF FLUID CLEANLINESS DATA SHEETS

AS4059 FLUID CLEANLINESS DATA SHEET (DS-1)
(For Differential Particle Counts)

Required Cleanliness: AS4059 Class _____ (equivalent to NAS1638)
Other_____

Sample Identity: Aircraft Application _____
System Location _____

Sampling Procedure: Bottle _____ Bottle Cleanliness Class _____
Online ____ Other (Describe) _____ Sample Volume_____

Counting Procedure: ___ Automatic Particle Counter ___ Optical Microscope
___ Method C (APC & Optical Microscope) ___ Electron Microscope

Automatic Particle Counter: Brand & Model _____
Sensor Model _____
Date Calibrated_____
Calibration Method _____
Sensor Flow Rate: _____ mL/min
Volume Counted per Run _____ mL

Dilution: Dilution Fluid _____Cleanliness _____

Size Range Counted					
Microscope Size, µm (1)	Automatic Particle Count or Microscope Size, µm(c) (2)	Particle Count	Volume Counted	Count per 100 mL	Contamination Class per Table 1
5 incl to 15 incl	6 to 14				
15 excl to 25 incl	14 to 21				
25 excl to 50 incl	21 to 38				
50 excl to 100 incl	38 to 70				
>100	>70				
AS4059 Contamination Code: [__/__/__/__/__]					
AS4059 Contamination Class:					
Notes/Visual Observations:					

(1) Based on longest dimension per report form in AS598 or ISO 4407.
(2) Based on projected area equivalent diameter per ISO 11171.

AS4059 FLUID CLEANLINESS DATA SHEET (DS-2)
(For Cumulative Particle Counts)

Required Cleanliness: AS4059 Class/Classes _____
Other _____

Sample Identity: Aircraft Application _____
System Location _____

Sampling Procedure: Bottle _____ Bottle Cleanliness Class _____
Online _____ Other (Describe) _____ Sample Volume _____

Counting Procedure: ___ Automatic Particle Counter ___ Optical Microscope
___ Method C (APC & Optical Microscope) ___ Electron Microscope

Automatic Particle Counter: Brand & Model _____
Sensor Model _____
Date Calibrated _____
Calibration Method _____
Sensor Flow Rate: _____ mL/min
Volume Counted per Run _____ mL

Dilution: Dilution Fluid _____ Cleanliness _____

Size Range Counted						
Microscope Size, µm (1)	Automatic Particle Count or Microscope Size, µm(c) (2)	Particle Count	Volume Counted	Dilution Ratio	Count per 100 mL	Contamination Class per Table 2
>1	>4					
>5	>6					
>15	>14					
>25	>21					
>50	>38					
>100	>70					
AS4059 Contamination Code: cpc[__/__/__/__/__/__]						
AS4059 Cumulative Particle Count Contamination Class:						
Notes/Visual Observations:						

(1) Based on longest dimension per report form in AS598 or ISO 4407.
(2) Based on projected area equivalent diameter per ISO 11171.