SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS4059

REV. E

Issued 1988-06
Revised 2005-05

Superseding AS4059D

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

FOREWORD

This revision has been made to incorporate the features of NAS 1638, which has been made Inactive for new design and not for use with automatic particle counters (APCs). In this version a method has been added applicable to users of NAS 1638 to allow easy conversion of specifications and future class determinations to AS4059 requirements. This revision allows particle counts to be determined by optical microscopy as well as alternate methods including automatic particle counters calibrated per the new ISO method, ISO 11171, and electron microscopes. The electron microscope technique is under development. Note that this revision may result in different cleanliness criteria from those obtained from previous versions of AS4059, including the ISO version, ISO 11218.

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1. SCOPE:

This SAE Aerospace Standard (AS) defines cleanliness classes for particulate contamination of hydraulic fluids and includes methods of reporting related data (Appendix A). The contamination classes selected are based on the widely accepted NAS 1638 cleanliness classes. Conversion from NAS 1638 cleanliness class specifications to AS4059 class specifications is defined. Comparison of the NAS 1638 classes to AS4059 classes is defined and the differences explained (Appendix B). This document provides versatility in identifying a maximum class in multiple size ranges, total number of particles larger than a specific size or designating a class for each size. NAS 1638 classes based on weight of particles are not applicable to either of these classes and are not included.

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. Web site: http://www.sae.org.

ARP598	Aerospace Microscopic Sizing and Counting of Particulate Contamination for Fluid Power Systems
AIR877	Aerospace-Particle Count Data Conversion and Extrapolation
ARP5376	Methods, Locations and Criteria for System Sampling and Measuring the Solid Particle Contamination of Hydraulic Fluids

2.2 AIA Publications:

Available from Aerospace Industries Association of America, Inc., 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3901. Tel. 703-358-1000. Web site: http://www.aia-aerospace.org.

NAS 1638	Cleanliness Requirements of Parts Used in Hydraulic Systems (Inactive for new design and not for use with automatic particle counters)

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 (Standard withdrawn in favor of ISO 11171)
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. AS4059 CLEANLINESS CLASSES:

When an AS4059 class is specified without suffix, the method specified in 3.2.2, Table 1, particles in each size range shall be used.

CAUTION: This revision of AS4059 may result in different cleanliness classes from those obtained with previous versions whenever the class was specified without any letter size suffix and for some cases when the class was specified with a suffix. Cleanliness classes with no suffix from previous versions of AS4059 were based on particles greater than 5 µm or 6 µm(c), whereas classes from this revision are based on the number of particles in each of the size ranges except the smallest, 1 µm or 4 µm(c). See 3.2.2 for more specifics.

3.1 Cleanliness Class Definitions:

Tables 1 and 2 provide differential and cumulative particle counts respectively for AS4059 cleanliness levels for microscopic particle counts and for counts obtained by particle counters calibrated to either the new or superseded ISO procedures. These tables list the cleanliness levels established to provide a set of criteria for specifying fluid cleanliness classes. The classes are based on contaminant size, count, and distribution. 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.

TABLE 1 - Cleanliness Classes For Differential Particle Counts (particles/100 mL) (3)

Classes	(1)	5 to 15 µm	15 to 25 µm	25 to 50 µm	50 to 100 µm	>100 µm
	(2)	6 to 14 µm(c)	14 to 21 µm(c)	21 to 38 µm(c)	38 to 70 µm(c)	>70 µm(c)
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	2 850	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

(1) Size Range, Optical Microscope, based on longest dimension as measured per ARP598, or APC Calibrated per ISO 4402:1991.

(2) Size Range, APC Calibrated per ISO 11171 or Electron Microscope, based on projected area equivalent diameter.

(3) Classes and contamination limits identical to NAS 1638.

TABLE 2 - Cleanliness Classes for Cumulative Particle Counts (particles/100 mL)

Classes	(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)
	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	1 217	217	39	7	1
3		6 250	2 432	432	76	13	2
4		12 500	4 864	864	152	26	4
5		25 000	9 731	1 731	306	53	8
6		50 000	19 462	3 462	612	106	16
7		100 000	38 924	6 924	1 224	212	32
8		200 000	77 849	13 849	2 449	424	64
9		400 000	155 698	27 698	4 898	848	128
10		800 000	311 396	55 396	9 796	1 696	256
11		1 600 000	622 792	110 792	19 592	3 392	512
12		3 200 000	1 245 584	221 584	39 184	6 784	1 024

(1) Size Range, Optical Microscope, based on longest dimension as measured per ARP598, or APC Calibrated per ISO 4402:1991.

(2) Size Range, APC Calibrated per ISO 11171 or Electron Microscope, based on projected area equivalent diameter.

3.2 Specifying and Determining Cleanliness Class:

3.2.1 Converting NAS 1638 Class Specifications to AS4059 Classes: NAS 1638 classes used in current specifications can be converted directly to AS4059 classes. In the simplest form, where NAS 1638 Class 6 is currently specified, AS4059 Class 6 applies. Similarly, to designate fluid cleanliness levels equivalent to NAS 1638 Class 6 one would specify: Fluid cleanliness shall meet AS4059 Class 6.

3.2.2 Determining AS4059 Class Using Differential Particle Counts: This method is applicable to those currently using NAS 1638 classes and desiring to maintain the methods, format, and results equivalent to those specified in NAS 1638.

Table 1 applies to acceptance criteria based on differential particle counts, and provides a definition of particulate limits for Classes 00 through 12. A class shall be determined for each particle size range. The reported class of the sample is the highest class in any given particle range size.

NOTE: The classes and particle count limits in Table 1 are identical to NAS 1638. Measurements of particle counts are allowed by use of an automatic particle counter (properly calibrated per ISO 11171 or ISO 4402:1991), or an optical or electron microscope. The size ranges measured and reported should be determined from Table 1 based on the measurement method.

3.2.3 Determining AS4059 Class Using Cumulative Particle Counts: This method is applicable to those using the methods of previous revisions of AS4059 and/or cumulative particle counts. The cleanliness levels for this method shall be specified by the appropriate class from Table 2. To provide versatility, the applicable cleanliness class can be identified in the following ways:

a. Basing the class on the highest class of multiple size ranges (see 3.2.3.1).

b. Total number of particles larger than a specific size (see 3.2.3.2).

c. Designating a class for each size range (see 3.2.3.3).

3.2.3.1 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. 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. The class designation shall be the class number followed by the letter codes representing the particle sizes analyzed.

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. (NOTE: This example provides the same results as AS4059 class 6, per 3.2.2.)

b. AS4059 Class 7A-E requires that the particles be counted in all sizes A through E and that the counts for each size shall be less than the maximum permitted per 100 mL for Class 7.

3.2.3.2 Classification Based on a Single Size: The AS4059 classes are based on a natural distribution of particle sizes previously used in NAS 1638. This natural distribution does not always 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. Therefore, AS4059 Revision B and earlier based the class on the 5 µm or 6 µm(c) size of interest since the smallest particle size usually has the highest class number.

Class 5B means no more than 9730 particles per 100 mL greater than size B (5 µm for optical microscopic counting 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 for size C and larger particles.

Examples:

a. AS4059 Class 5B

b. AS4059 Class 6C

3.2.3.3 Designating a Class for Each Size Range: Automatic particle counters can 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. A class may be designated for each size from A through F. An example is provided below:

7B/6C/5D 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. It also 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

4. SAMPLING AND ANALYSIS:

4.1 Procedures:

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

4.2 Particle Count Measurement:

Particle counts shall be made in accordance with one of the following methods:

4.2.1 Method A - Automatic Particle Counters: Automatic Particle Counters (APCs) shall be calibrated per ISO 11171.

NOTE: ISO 4402:1991 may be used for automatic particle counter calibration when the original particle size ranges in NAS 1638 are reported; i.e., 5, 15, 25, 50, and 100 µm.

4.2.2 Method B - Optical Microscope: Optical microscopic particle counting shall be conducted in accordance with ARP598.

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 (Size Code F on Table 2). 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 NAS 1638 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.

5. DETERMINATION AND REPORTING OF CLEANLINESS CLASS:

5.1 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 (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).

NOTE: Users have permission to reproduce the data sheet without copyright infringement.

5.2 Reporting of Cleanliness Class:

The fluid cleanliness classification is determined from either Table 1 or 2 by the number of particles in each range or greater than the applied sizes depending on specification method.

6. NOTES:

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

6.1 Data Analysis:

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

6.2 Sampling Errors:

Extracting a fluid sample from a fluid system may 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 should be considered as a possible cause, and additional sampling is recommended. If confidence is obtained that the large particles are in error, consideration can be made to set the cleanliness requirements based on the smaller particle sizes, which may minimize errors caused by poor sampling techniques.

6.3 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.

6.4 Revisions:

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.

6.5 Key Words:

Particle count, particle size, cleanliness class, contaminant level, contamination

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APPENDIX A

Required Cleanliness: AS4059 Class _____(equivalent to NAS 1638)
Other _____

Sample Identity: Aircraft Application _____
System Location _____

Sampling Procedure: Bottle _____ Bottle Cleanliness Class _____
On-line ____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					
APC (ISO 4402:1991) or Optical Microscope Size, µm *	**APC (ISO 11171) or Electron Microscope Size, µm(c)**	**Particle Count**	**Volume Counted**	**Count per 100 mL**	**Class per Table 1**
5 to 15	**6 to 14**				
15 to 25	**14 to 21**				
25 to 50	**21 to 38**				
50 to 100	**38 to 70**				
> 100	**> 70**				
AS4059 (highest) Class:					
Notes/Visual Observations:					

* Report optical microscope counts in accordance with report form in SAE ARP 598.

FIGURE A1 - AS4059 Fluid Cleanliness Data Sheet (DS-1)
(For Differential Particle Counts)

Required Cleanliness: AS4059 Class/Classes _____
Other _____

Sample Identity: Aircraft Application _____
System Location _____

Sampling Procedure: Bottle _____ Bottle Cleanliness Level _____
On-line ____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							
APC (ISO 4402:1991) or Optical Microscope Size, µm *	APC (ISO 11171) or Electron Microscope Size, µm(c)	Size Code	Particle Count	Volume Counted	Dilution Ratio	Count per 100 mL	Class per Table 2
> 1	> 4	A					
> 5	> 6	B					
> 15	> 14	C					
> 25	> 21	D					
> 50	> 38	E					
> 100	> 70	F					
AS4059 Class per Table 2:							
Notes/Visual Observations:							

* Report optical microscope counts in accordance with report form in SAE ARP 598.

FIGURE A2 - AS4059 Fluid Cleanliness Data Sheet (DS-2)
(For Cumulative Particle Counts)

APPENDIX B
DIFFERENCES BETWEEN AS4059 AND NAS 1638

B.1 SCOPE:

This Appendix is to provide information on the variations between NAS 1638 and AS4059.

B.2 BACKGROUND:

When NAS 1638 was developed, the principle means of counting particles was the optical microscope with particles sized by the longest dimension per ARP598. When APCs came into use this provided a method of analyzing a sample much faster that the ARP598 method. A method of calibrating APCs was developed, although they measured area and not length, such that comparable results to that of ARP598 could be obtained from the same sample. Now, automatic particle counters are the primary method used to count particles and the projected area of a particle determines size. Because of the way particles are sized with the two methods, automatic particle counters and optical microscopes do not always provide the same results. NAS 1638 has now been made inactive for new design and has been revised to indicate it does not apply to use of automatic particle counters. This standard incorporates the features of NAS1638, including the use of ARP598, and is intended to provide a uniform classification system independent of the particle size analysis method.

Prior to ISO 11171, the previous APC calibration method most widely utilized was ISO 4402, which used Air Cleaner Fine Test Dust (ACFTD) as the reference calibration material. ACFTD is no longer manufactured and the ISO 4402 method using this dust has been made obsolete. The industry developed the method ISO 11171, which supercedes ISO 4402, with a calibration standard based on NIST-certified samples of ISO 12103-1 A3 medium test dust suspended in hydraulic oil. There is a difference between the particle measurements by ISO 4402 and ISO 11171. To retain the same cleanliness measure, calibrations using ISO 11171 are conducted to a corrected particle count scale. For example, particles reported as 5 µm with the ISO 4402 method are reported as 6 µm(c) by the ISO 11171 method. In fact 5 µm corresponds to 6.4 µm(c), and some round off was conducted for simplification.

B.2.1 Differences between NAS 1638 and AS4059:

AS4059 was developed to have classes equivalent to NAS 1638. However, there are differences.

B.2.1.1 Cumulative Counts versus Differential Counts in a Size Range: NAS 1638 was designed for use with an optical microscope and therefore particle counts were specified in particle size ranges. Section 3.2.2 of this standard utilizes this same approach, so as to minimize differences in resulting fluid classifications from the original NAS 1638 standard. AS4059 was originally designed for use primarily with automatic particle counters, which can easily count particles larger than a selected size. Therefore, 3.2.3 provides a method for reporting cumulative particle counts to determining the AS4059 class, which can be useful for evaluating filter performance, for example. Cumulative particle counts need to be calculated If particle counts are made using an optical microscope in the size intervals specified by ARP598. The cumulative particle counts at each size can easily be calculated by adding all the counts for larger sizes. For example, to determine the number of particles greater than 15 µm, simply add the particles obtained in the 15-25, 25-50, 50-100, and >100 size ranges.

B.2.1.2 Counting of Smaller Particles: AS4059 allows the analysis and reporting of smaller particle sizes than NAS 1638.

B.2.1.3 Counting Large Particles and Fibers: In some samples, it has been observed that many of the particles larger than 100 micrometers are fibers. However, automatic particle counters size particles based on projected area rather than longest dimension and do not differentiate between fibers and particles. Therefore, fibers will be reported as particles with dimensions considerably less than the length of the fibers. A problem with fibers is that they may not be present in fluid in the system but rather have been introduced as the result of poor sampling techniques or poor handling during analysis.

B.2.1.4 Combination Method of Particle Counting: Section 4.2.3 refers to particle counting by the combination method, which utilizes both 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 4-38 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 on-line.

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