NATO STANDARD

AFLP - 3713

DETERMINATION OF PARTICULATE MATTER IN AEROSPACE HYDRAULIC FLUIDS USING A PARTICLE ANALYSER

Edition A
Version 2
October 2014

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED FUELS AND LUBRICANTS PUBLICATION

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NATO LETTER OF PROMULGATION

31 October 2014

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RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

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RECORD OF SPECIFIC RESERVATIONS

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SECTION 1 GENERAL

0101. Participating nations agree that the automatic particle counter and associated processes to be used shall fulfill the requirements detailed in Section 2. When such a particle counter is used for determining the particulate matter in aerospace hydraulic fluids, one of the calibration methods detailed in Section 3 shall be followed. Section 4 provides general information on hydraulic fluid contaminants along with the recognized tables used for aerospace and hydraulic fluid power systems classification.

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SECTION 2 MINIMUM PERFORMANCE REQUIREMENTS FOR AN AUTOMATIC PARTICLE COUNTER (APC) SUITABLE FOR DETERMINING PARTICULATE MATTER IN AEROSPACE HYDRAULIC FLUIDS AND ASSOCIATED PROCESSES

0201. The various steps in performing a successful cleanliness evaluation on a hydraulic fluid sample are relatively simple. The operator requires a period of familiarization since standard laboratory procedures are used. All steps in the procedure must be carried out each time in a careful, unhurried manner without diversion.

0202. The APC bench should be neatly organized in that only the APC accessories and the sample(s) to be processed are in the working area. Care must be taken to ensure that no errors are made in the identification of samples, their respective count sequence and count records

0203. A successful cleanliness evaluation is one where a minimum of extraneous contaminant is present. This can only be assured by adhering to proper procedures and by careful attention to cleanliness throughout the cleanliness evaluation process.

ENVIRONMENT AND ASSOCIATED EQUIPMENT

0204. The instrument should preferably be installed on a dedicated work station located in a clean area remote from high particulate contaminant areas such as a machine shop, paint shop or any place where local grinding, filing or buffing operations are carried out. The room should be used for no other activity except other laboratory operations requiring similar levels of cleanliness.

0205. The room should contain only the furniture and equipment required for use with the equipment. These items are as follows:

- Dedicated workstation preferably a smooth-topped bench approximately 90 to 95 cm (36 to 38 inches) in height with sufficient work surface to hold the APC, Bottle Sampler (BS) Offline with the associated equipment.
- A grounded or bonded waste drum and funnel.

0206. The instrument is sensitive to line voltage variations, therefore it is recommended to use an electrical line filter (power bar) to prevent any incoming surges.

BOTTLE CLEANING PROCEDURE

0207. Procurement of clean sample containers shall meet the requirements detailed in ISO 11171 and 3722 or the approved sampling bottles shall be cleaned by the base unit responsible for the cleanliness evaluation of hydraulic fluid. The cleaning process has to take place in a well ventilated area, preferably under a laminar flow bench. The bottle cleaning procedure for the glass and plastic sample bottle requires units to use an air pressurized dispensing system with filterjet solvent dispenser along with 0.5 micrometer filtering membrane. Air supply can be central system or a dedicated pump. Thoroughly rinse bottles and bottle caps three times with an approved solvent such as MIL-PRF-680 or heptane to ensure cleanliness. After the three consecutive flushings of the bottles, invert bottle and cap to drain as much solvent as possible into waste container. The recapped bottle is then ready for sample taking. The film of clean solvent remaining in the bottle will not interfere with subsequent evaluations in regard to particle counting.

SAMPLE-TAKING PROCEDURE

0208. Samples from aircraft hydraulic systems and hydraulic test stands should be as representative of the system fluids as possible. The sample must not contain any foreign substance generated by the sample taking procedure.

NOTE: Wherever possible, preference should be given to an on-line condition monitoring by connecting the APC directly on the aircraft or on the return line between the aircraft and hydraulic test stands to obtain the most representative results.

0209. The following precautions and procedures apply when preparing to take a representative sample from a system in order to perform an accurate APC particle count:

- Work area to be clean and draft free.

- Clean the sampling outlet in accordance with the manufacturer’s instructions. Lint-free cloth is recommended while regular cloth is not considered suitable. Blow clean with dry air (optional).

- Initiate the flow of fluid by whatever means is appropriate and allow an initial quantity of fluid to flow into a waste receptacle. The volume used is dependent of the system being evaluated. This serves to flush away any contaminants in the sampling line or generated by the mechanical operation of valves, etc.

NOTE: Once fluid flow has been initiated, it should not be interrupted or turned off until after the sample bottle has been filled to the proper level and capped.

- When size and volume permits, fill the sampling bottle to a 1/3 with the fluid from the flowing stream, agitate the fluid in a swirly motion to rinse any contaminant from the inside of the bottle and dump contents into waste container. Repeat this step two times. For small hydraulic fluid equipment, ultra-clean bottles should be used.

NOTE: Handle bottle and cap in such a way that contaminants cannot enter it from external sources. Never allow the open neck of the bottle to rub against, or come in contact with the fluid outlet or hose.

- Fill the sampling bottle to a level approximately 30 ml (2 cm) from the top and replace cap tightly. The free air space between the bottle cap and fluid is extremely important and must be provided for the operator to properly agitate the fluid prior to performing a particle count.

- Terminate fluid flow from sampling point.

SAMPLE MIXING AND DE-GASSING

0210. The sample is inspected visually by the technician to determine the presence of free water and/or visible particulate. The presence of free water can render the sample cloudy. Solubility of water in hydraulic oils is temperature dependent. Cases where water and/or visible particulate are present, no evaluation using the APC will be performed. This situation is biased towards unacceptability and further investigation to determine the source of contamination should be undertaken. If there is no visual presence of water or particulate, the sample can be evaluated and processed using the APC.

0211. The bottle is then vigorously hand shaken for 3 minutes by hand or by automatic shaker. As sedimentation of contaminant in a sample will occur, the sample shall be analyzed without delay, once agitated.

0212. The bottle sample can be de-gassed either by applying a vacuum or by immersing it into an ultrasonic bath until no surfacing of air bubbles. In both cases, the sample is considered fully de-gassed when no air bubble can be seen at the surface of the fluid.

PRINCIPLE OF OPERATION AUTOMATIC PARTICLE COUNTER (APC)

0213. Thorough mixing of the liquid sample to suspend all particles. Direct sizing and counting of solid particle contamination in the liquid sample using an automatic particle-count instrument.

0214. The APC used operates according to the principle of intermittent light-beam (light extinction principle). As soon as a specified liquid volume has passed the measuring area of the particle counter sensor, counting is terminated and results are recorded.

0215. The APC can be attached to an in-line sensor strategically placed in the hydraulic system or to an automatic bottle sampler (ABS). The APC provides a display of the size and number of particles in the fluid at that point in the system or in a bottle sample. Results are interpreted in either the SAE AS4059, ISO 4406 or NAS 1638 standard.

0216. A microprocessor controlled optical scanning device is used to measure and count particles within the fluid at +1, +5, +15, +25, +50 and +100 micrometres (μm) sizes based on ISO 4402 calibration protocol or +4, +6, +14, +21, +38, +70 μm (c) based on ISO 11171 calibration protocol . A permanent record of results is generated and can be printed out and/or stored in memory.

PARTICLE ANALYSIS

0217. The level of contamination in an hydraulic fluid sample is determined using a light extinction principle.

0218. The fluid flows through a transparent measuring cell. The flow rate of the oil through the optical cell (and hence the particle velocity) is accurately controlled by means of a motorized syringe pump or gas pressure depending on instruments. A light source is fixed on one side of the cell and a photoelectric diode on the other side. When a test is performed the photoelectric diode produces a voltage proportional to the illumination. A particle within the oil causes a shadow effect. The shadow effect results in a reduction in the illumination and thus a reduction in the voltage of the photo-electric diode. The magnitude of this reduction is a measure of the particle size. Presence of moisture in the oil may interfere with particle count.

0219. The optical window of most measuring cells has a width of 400 μm. In order to achieve greater accuracy most APC incorporate in their design a system, which magnifies the image of each particle by a factor of five, and projects it into a photodiode.

0220. The reduction in voltage causes by the shadow of a particle is integrated with the time it takes to pass over an optical mask on the photodiode to produce a value equating to the particle area. Each particle is sized and counted relative to 6 calibrated values. The count is then stored in one of six channels, +1, +5, +15, +25, +50 and +100 μm or +4, +6, +14, +21, +38, +70 μm (c) according to the particle size.

0221. If the counting capacity of the sensor is exceeded, it may become necessary to dilute the sample. However, this should be avoided whenever possible. Ensure that the instrument has been switched on long enough to become stabilized. The values obtained after dilution can be unreliable.

0222. Adjust the instrument to the calibration threshold values, which have been determined during the calibration of the instrument in accordance with one of the methods specified in Section 3.

0223. Set the particle-count instrument to either cumulative counting above a specific size or differential counting within specified size ranges in accordance with the calibration standards ISO 11171 or ISO 4402.

0224. Rinse the sensor with a small amount of the sample liquid.

0225. Adjust the setting of the gas pressure in order to obtain the same flow volume as for the calibration.

0226. Proceed with the counting of the sample in accordance with the manufacturer's instructions.

0227. Carry out at least two measurements with identical volumes per sample. Results are averaged in order to be classified as per 0229.

0228. Once the counting procedure has been completed, remove the sample bottle and rinse the sensor with an approved solvent or compatible fluid.

EXPRESSION OF RESULTS

0229. The results shall be expressed either as differential or cumulative count as the number of particles per 100 ml, see Table 1 or either as cumulative count above specific sizes as the number of particles per ml, see Table 2.

0230. The type of calibrations used for instrument calibration shall be included in the test report.

Table 1. Typical APC Results
Expressed in NAS 1638 based on ISO 4402 Calibration or
Expressed in AS4059 based on ISO11171 Calibration

Size Range NAS1638 ISO 4402	Size Range AS4059 ISO 11171)	Particle Count (Differential)	Particle Count (Cumulative)
5-15 µm	6-14 µm(c)	123456	124826
15-25 µm	14-21 µm(c)	1234	1370
25-50 µm	21-38 µm(c)	123	136
50-100 µm	38-70 µm(c)	12	13
Greater than 100 µm	Greater than 70 µm(c)	1	1

Table 2. Typical APC Results
Expressed in ISO 4406 based on ISO 11171 Calibration

Size	Particle Count (Cumulative)	ISO Code
≥4 µm(c)	1248	17
≥ 6 µm(c)	13.7	11
≥ 14 µm(c)	1.36	8

SECTION 3 RECOGNISED METHODS FOR THE CALIBRATION OF AUTOMATIC PARTICLE COUNTER (APC) USED FOR AEROSPACE HYDRAULIC FLUID CLASSIFICATION

SCOPE

0301. The primary calibration of the instrument shall be carried out in accordance with the procedures laid down by the manufacturer using a recognised reference fluid. The calibration of instruments shall be carried out at least annually as well at any time when the sensor or the electrical part of the instrument is altered. It is understood that APCs need to be calibrated with only one of the following recognized methods. Nations may institute a proficiency program, which consists of a correlation using working standard fluid between a reference laboratory instrument, calibrated with primary standard, and a field instrument.

0302. The information obtained from automatic counters is directly related to the calibration and setting of the instrument prior to use. Care should be taken to confirm the validity of the relative calibration before comparison is made with results obtained on other similar instruments in other locations, otherwise the results cannot be related in absolute terms.

RECOGNISED METHODS

0303. One of the following methods shall be used for the calibration of APCs:

- International Standard ISO 4402 - Hydraulic Fluid Power – Calibration of automatic-count instruments for particles suspended in liquids – Method using classified AC fine test dust contaminant.

  This international standard defines a procedure for the calibration of automatic-count instruments for particles suspended in liquids when used for the determination of particle size distribution of contaminants encountered in hydraulic power applications. The calibration is conducted by diluting a suspension of AC Fine Test Dust (ACFTD) in a compatible fluid which will have a known particle size distribution for each single concentration, which is below the saturation level of the instrument. Only secondary ACFTD solution is available commercially. A calibration with a primary ACFTD standard is not possible because a primary ACFTD standard is not available.

- International Standard ISO 11171 - Hydraulic Fluid Power – Calibration of APC for liquids.

The primary particle-sizing calibration is conducted using suspensions of ISO medium test dust (ISO 12103-A3 or ISO MTD) with particle size distribution certified by the National Institute of Standards and Technology (NIST). A secondary method with traceability to NIST uses suspensions of the same ISO MTD as the primary method but which are independently analysed using a particle counter calibrated by the primary method. Concentration limits are determined through the use of serial dilutions of a concentrated suspension.

SECTION 4 HYDRAULIC FLUID CONTAMINATION

GENERAL

0401. Hydraulic fluid contamination may be described as any foreign material or substance whose presence in the fluid is capable of adversely affecting system performance or reliability. It may be in the form of grit, sand, dirt, rubber, rust, sealant, dust, metal, fibres of both organic and inorganic origin, or any other such substance, which is not soluble in the hydraulic fluid. Likewise, any fluid or gas (air) foreign to the basic system fluid is considered a contaminant. Regardless of its origin, any form of contamination in the hydraulic system will impede performance and, in some cases, seriously affect safety. Hydraulic contamination control consists of those requirements, techniques and practices, which minimize and control fluid contamination.

SOURCES OF CONTAMINATION

0402. Contamination in an operating hydraulic system normally originates from several different sources, with its rate of introduction being dependent upon numerous factors, several of which are directly related to wear and chemical reaction. The amount of contamination in a system will increase with use unless contamination removal reverses the natural trend. Production of contaminants is also related to the number of components in the hydraulic system, increasing with the number of system components. The rate of contamination from external sources cannot be readily predicted and a hydraulic system can be seriously contaminated by maintenance malpractices leading to the introduction of large amounts of external contaminants. Contaminants in hydraulic fluids may be grouped into several types, and generally classed as organic, metallic, dust and dirt, and water, all of which can be introduced through poor maintenance practices. Poorly maintained ground support equipment, for example, hydraulic test stands, may also be a source of contamination.

PARTICULATE CONTAMINATION

0403. Most contaminants cannot be seen with the naked eye and are measured in microns. Examples of measurements in microns are shown below:

- 1 micron measures .000039 inches;
- 15 microns measure .00058 inches; and
- 40 microns measure .00157 inches.

0404. Human hair measures 40 to 120 microns. The lowest limit of visibility with the naked eye is 40 microns. Compare these figures with the close tolerances of modern day aircraft components. For example, the nosewheel steering shut–off valve, Part 6770–3, used on the Tutor aircraft has a diametrical clearance between the spool and sleeve of 2 – 40 microns. Particles in the four to eight micron range could enter this clearance and cause jamming, binding, and scoring, or render the valve completely inoperative.

0405. Several methods and instruments based on different principles can be used to determine the size distribution of the particles suspended in aerospace fluids. A graphic representation of the relative size of particles measured in microns is shown in Figure 1 (p.4-7). If the technique is the optical microscope then it will be sized by its longest dimension (1a) giving 13 μm (5). If it is analysed using an APC in accordance of ISO 11500, it will be sized according to its projected area equivalent diameter giving 10 μm (7).

0406. The level of contamination in hydraulic systems is measured in terms of the quantity of specified size particles present in 100 millilitres of the hydraulic fluid sample. Figure 2 (p. 4-8) gives the NAS 1638 contamination limits per class. Figure 3 (p. 4-9) provides the ISO SAE AS4059 limits per class. NAS 1638 has been widely used in the aerospace industry for specifying system fluid cleanliness in hydraulic systems. Because of its long use and familiarity, its classes have been retained as a basis for SAE AS4059. This ISO classification standard extends NAS 1638 to include cumulative measurement of particulate contamination in the fluid system down to one micrometer (μm) and Class 000. In addition, SAE AS4059 simplifies the reporting and interpretation of contamination data. Figure 4 (p. 4-10) provides, for ease of use and to simplify the reporting of particle count data by converting the numbers of particles into broad classes or codes, where an increase in one code is generally doubling of the contamination level used for industrial oils and proposed for aviation turbine fuels based on ISO 4406. The reported sizes are ≥ 4 μm (c), ≥ 6 μm (c), ≥ 14 μm (c), the last two of these being equivalent to the 5 μm and 15 μm particle sizes obtained using the ISO 4402 method of calibrating APCs. ISO 4402 has been replaced in most part by ISO 11171. Throughout the International Standard, the use of μm (c) means that particle size measurements are carried out using an APC which has been calibrated in accordance with ISO 11171.

ORGANIC CONTAMINANTS

0407. Most very fine contaminants are organic materials produced chemically in the hydraulic fluid during normal service as a result of oxidation or polymerization processes. Minute non–metallic particles of O–rings, seals, gaskets, synthetic rubber hoses and PTFE (Teflon®) are usually present and may contribute to the process of oxidation or polymerization. Oxidation of hydraulic fluid increases with pressure and temperature, although chemicals are added to the hydraulic fluid during manufacturing to minimize such oxidation. Oxidation products will appear as organic acids, asphaltics, gums and varnishes. These products combine with particles from sealing materials and dust to form sludge. Some oxidation products are oil soluble and cause the hydraulic fluid to increase in viscosity; other oxidation products are not oil soluble, and these form some of the sediment, which is trapped by filters. Hydraulic fluid additives retard gum formation under normal operating conditions, but continued service at high temperatures decreases the resistance to oxidation and some soluble contaminants may be formed.

0408. Another form of chemically–produced contamination results from a tendency of the hydraulic fluid to react with certain types of synthetic rubber seals. Hydraulic system O–rings and 6.6-polyamide (nylon®) or PTFE back–up rings in valves and hydraulic actuators normally wear during service and contribute to the process. Synthetic products in contact with the hydraulic fluid may include chloroprene (neoprene®), polysulfide (Thiokol®), silicones, fluoro–carbon rubber, and chloro-sulfate-polyethylene (hypalon®). These excellent rubber synthetics are resistant to chemical–reaction with petroleum–based hydraulic fluid and retain their resiliency during heavy service. Nevertheless, small wear particles are continuously released into the hydraulic fluid so that non–metallic contaminants in a hydraulic system usually increase as a function of time.

METALLIC CONTAMINANTS

0409. Metallic contaminants are almost always present in a hydraulic system and will range in size from microscopic particles to particles readily visible to the naked eye. These particles are the result of wearing and scoring of bare metal parts and plating materials such as silver and chromium. These wear products and other foreign metal particles such as steel, aluminium, and copper may also act as metallic catalysts in the formation of oxidation products. Copper and copper alloys are also effective metallic catalysts; therefore, the use of copper, brass or bronze in hydraulic component design should be kept to a minimum. Although practically all metals commonly used for parts fabrication and plating may be found in hydraulic fluids, most metallic materials detected are ferrous, aluminium, and chromium. Because of their continuous high-speed internal movement, hydraulic pumps usually contribute most of the metallic particulate contamination present in hydraulic systems. Metal particles are also produced by other hydraulic system components such as hydraulic valves and actuators, due to body wear.

DIRT AND DUST

0410. This contamination group includes dust, paint particles, dirt and silicates. Glass particles from glass shot bead peening and blasting may also be found as contaminants. Glass or silicate particles like sand are very undesirable contaminants due to their abrasive effect on synthetic rubber seals and the very fine surfaces of critical moving parts. Atmospheric dust, dirt, paint particles, and other materials are often drawn into the hydraulic system from external sources. For example, the wet piston shaft of a hydraulic actuator may draw some of these foreign materials into the cylinder, past the wiper and dynamic seals, and the contaminant materials are then dispersed in the hydraulic fluid. Contaminants may also enter hydraulic fluids during maintenance when tubing, hoses, fittings, and components are disconnected or replaced. It is important that all exposed fluid ports be sealed with approved protective closures to minimize such contamination.

WATER

0411. Hydraulic fluids are adversely affected by dissolved, entrained, or free water often found in hydraulic systems. Water concentration in hydraulic oils is temperature dependent. The presence of water may result in the formation of ice, corrosion of metallic surfaces and promotion of chemical reactions, which may produce oxidation products. Water may be introduced inadvertently through improper maintenance or, in some cases, as a result of system design. Vented hydraulic reservoirs not adequately protected by desiccators are an example of the latter. When water separates from hydraulic fluid, it often collects at filter bowls but will also settle at other more critical locations in the system. Water must be considered a serious contaminant and corrective action must be taken to cleanse the system of all detectable traces.

OTHER FOREIGN FLUIDS

0412. Hydraulic systems can be seriously contaminated by foreign fluids other than water. This type of contamination, although fortunately rare, is generally a result of lubrication oil, engine fuel, or the incorrect type of hydraulic fluid inadvertently being introduced into the system during servicing

In addition, some models of aircraft employ hydraulic oil coolers which, when leaky, can result in fuel intrusion into the hydraulic system. Contamination with a foreign fluid, when suspected, can usually be verified by chemical, physical and physico-chemical analysis of a fluid sample.

SOLVENT CONTAMINATION

0413. Solvent contamination is a special form of foreign fluid contamination in which the original contaminating substance is a chlorinated solvent, which, when introduced into a hydraulic system, will react with any water present to form highly corrosive acids. Solvent contamination must be prevented by proper selection of cleaning agents when performing hydraulic system maintenance. Extreme care must be exercised when utilizing solvents to clean internal surfaces of system components that will come in contact with hydraulic fluid. Ensure that all surfaces are dry and free of any traces of residual solvent prior to installation or assembly. Clean unused hydraulic fluid is recommended for those cleaning applications where solvent contamination may be a problem. After cleaning, all hydraulic system components or Aircraft Maintenance Support Equipment (AMSE) are to be flushed with their operational hydraulic fluid before being put into operation.

AIR/NITROGEN

0414. Whenever lines are broken for the removal or installation of hydraulic system components, air inevitably gets into the hydraulic system. Air may also be introduced from ground support equipment. Actuator rod seals and bootstrap reservoir piston seals may pump small amounts of air into the system during each stroke. Improper maintenance procedures, such as failure to fill filter bowls with fluid when replacing elements, are further sources for the introduction of air. Despite the most rigorous bleeding procedure, a relatively large percentage of this air remains trapped.

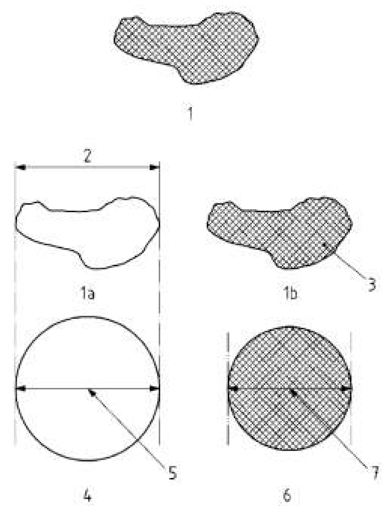
0415. Air inclusion in the hydraulic system of present day, high performance aircraft is highly undesirable. The entrained air tends to increase compressibility of the fluid, making the system elastic, noisy, and erratic. Compression of this air generates heat and can increase oxidation. Efficiency of pumps is reduced because air bubbles tend to expand on the inlet side and collapse on the discharge side. This collapsing can produce cavitation type erosion and it can cause a wide variety of symptoms. Nitrogen charged equipment can leak into the hydraulic oil and can cause undue foaming which may lead to failure of hydraulic pumps.

0416. The entrained air can be detected by a wide variety of symptoms; some just annoying, some serious, but all potentially deadly. Typical problems caused by the presence of air are:

- slow system response due to increased compressibility and elasticity of fluid;
- erratic and jerky action during component operation;
- reduction of system stiffness;
- increased power consumption required to drive pumps;
- higher fluid temperatures;
- cavitation in pumps and slide valve metering gland areas;
- inability of system to develop full pressure;
- erosion (from cavitation) of pumps, metering orifices and servo valves; and
- foaming of hydraulic oil and failure of hydraulic pumps.

SAMPLING

0417. When measuring the solid particle contamination of hydraulic fluids, the selection of the sampling point in the hydraulic system and the way of taking it are of prime significance to the quality of the sampling and shall be in accordance with ISO 5884. The sampling can be accomplished using sample bottles or using an on-line monitor. It is essential that the fluid sample being analysed is taken from a turbulent flow rather than a laminar flow and be representative of the hydraulic system being evaluated.



1 Particle to be analyzed
1a Sized by microscope or image analysis based on “longest dimension”
1b Sized by APC calibrated as per ISO 11171 set up to give the “diameter of a sphere with the same equivalent projected area”
2 Particle longest dimension (d = 13μm)
3 Particle projected area (A = 78.5 μm^2)
4 Sphere with same longest dimension as actual particle
5 Diameter of sphere with same longest dimension (d = 13 μm)
6 Spherical particle with same projected area as actual particle (A = 78.5 μm^2)
7 Diameter of sphere with same projected area as actual particle (d = 10 μm(c))

Figure 1 — Effect of the analysis technique on the reported size of a particle

Particle Size Range (Microns) Plage de la taille des particules (micro–mètres)	Per Class Par catégorie													
	00	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
5 to/à 15	125	250	500	1 000	2 000	4 000	8 000	16 000	32 000	64 000	128 000	256 000	512 000	1 024 000
15 to/à 25	22	44	89	178	356	712	1 425	2 850	5 700	11 400	22 800	45 600	91 200	182 400
25 to/à 50	4	8	16	32	63	126	253	506	1 012	2 025	4 050	8 100	16 200	32 400
50 to/à 100	1	2	3	6	11	22	45	90	180	360	720	1 440	2 880	5 760
Over 100 au–dessus de	0	0	1	1	2	4	8	16	32	64	128	256	512	1 024

NOTES

1. NAS 1638 based on 100 ml sample size

2. Numbers in blocks indicate number of particles within that size range.

NOTA

1. Selon la norme NAS 1638, l'échantillon est de 100 ml.

2. Les chiffres correspondent au nombre de particules de taille spécifiée.

Figure 2 Table of Cleanliness Requirements of Hydraulic Systems (NAS 1638)
Figure 2 Tableau des exigences de propreté des systèmes hydrauliques (NAS 1638)

		MAXIMUM CONTAMINATION LIMITS (Particles/100 mL) LIMITES DE CONTAMINATION PARTICULAIRE MAXIMALE (particules / 100 ml)					
Size, ISO 4402 Calibration* or Optical Microscope Count* Taille, étalonnage ISO 4402* ou comptage avec microscope optique*		>1 µm	>5 µm	>15 µm	>25 µm	>50 µm	>100 µm
Size, ISO 11171 Calibration or Electron Microscope** Taille, étalonnage ISO 11171 ou comptage avec microscope électronique**		>4 µm	>6 µm	>14 µm	>21 µm	>38 µm	>70 µm
Size Code		**A**	**B**	**C**	**D**	**E**	**F**
CLASSES CATÉGORIES	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	6,250	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	16
	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	1,020

NOTES

* Particle size based on longest dimension

** Particle size based on projected area equivalent diameter

NOTA

* Taille de particule selon la dimension la plus grande

** Taille de particule selon le diamètre équivalent de la surface projetée

Figure 3 - SAE AS4059 Cleanliness Levels By Particle Count
Figure 3 - SAE AS4059 Niveau de classification des comptes de particules

Allocation of scale numbers

Number of particles per ***ml***		Scale number
More than	Up to and including	
2 500 000		> 28
1 300 000	2 500 000	28
640 000	1 300 000	27
320 000	640 000	26
160 000	320 000	25
80 000	160 000	24
40 000	80 000	23
20 000	40 000	22
10 000	20 000	21
5 000	10 000	20
2 500	5 000	19
1 300	2 500	18
640	1 300	17
320	640	16
160	320	15
80	160	14
40	80	13
20	40	12
10	20	11
5	10	10
2.5	5	9
1.3	2.5	8
0.64	1.3	7
0.32	0.64	6
0.16	0.32	5
0.08	0.16	4
0.04	0.08	3
0.02	0.04	2
0.01	0.02	1
0	0.01	0

Figure 4- ISO 4406; Hydraulic fluid power -- Fluids -- Method for coding the level of contamination by solid particles

Figure 4 – ISO 4406; Transmission Hydrauliques – Méthode de codification du niveau de pollution particulaire solide

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