FLUID CONDITION AND FILTRATION HANDBOOK

Manual of analysis and comparison photographs

MPFILTRI®

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THE COMPLETE
HYDRAULIC FILTRATION
& ACCESSORY RANGE

CMP
Contamination Monitoring Products

...because contamination costs!

70–80% of all failures
on hydraulic systems and up to 45%
of all bearing failures are due
to contaminants in the hydraulic fluid

In hydraulic fluid power systems, power is transmitted and controlled through a liquid under pressure within an enclosed circuit. The liquid is both a lubricant and a power transmitting medium.

The presence of solid contaminant particles in the liquid inhibits the ability of the hydraulic fluid to lubricate and causes wear to the components. The extent of contamination in the fluid has a direct bearing on the performance and reliability of the system and **it is necessary to control solid contaminant particles to levels that are considered appropriate for the system concerned**.

A quantitative determination of particulate contamination requires precision in obtaining the sample and in determining the extent of contamination. Hydraulic **Automatic Particle Counters (APC) - MP Filtri Products**, work on the light-extinction principle. This has become an accepted means of determining the extent of contamination. The accuracy of particle count data can be affected by the techniques used to obtain such data.

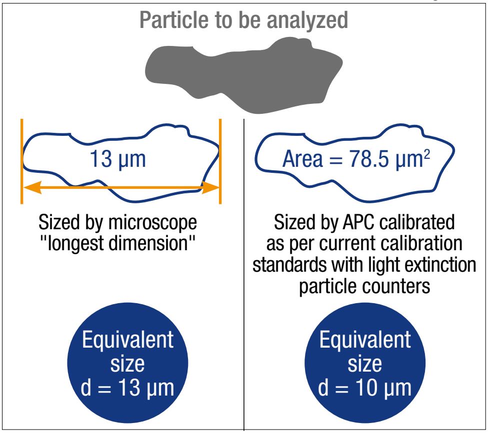
The NAS 1638 reporting format was developed for use where the principle means of counting particles was the optical microscope, with particles sized by the longest dimension per ARP598. When APC's came in to use this provided a method of analysing a sample much faster than the ARP598 method. A method of calibrating APC's 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, APC's 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, APC's 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 APC's.**

PARTICLE SIZE ANALYSIS

Several methods and instruments based on different physical principles are used to determine the size distribution of the particles suspended in aeronautical fluids. The numbers of particles found in the different size ranges characterize this distribution. A single particle therefore has as many equivalent diameters as the number of counting methods used.

Figure 1 shows the size given to the particle being analysed (shading) by a microscope as its longest chord and an APC calibrated in accordance with current calibration standards with light extinction particle counters using the Standard Reference Material NIST SRM 2806 sized by the equivalent projected area.

Figure 1



DIFFERENCES BETWEEN NAS 1638 AND AS4059E

AS4059E was developed as a replacement/equivalent to the obsolete NAS 1638 format, where table 2 relates to the old AS4059D standard and table 1 is the equivalent NAS 1638 standard. However, there are differences. Particularly in Table 2, (Cumulative Particle Counts).

COUNTING OF SMALLER PARTICLES

AS4059E allows the analysis and reporting of smaller particle sizes than NAS 1638.

COUNTING LARGE PARTICLES AND FIBRES

In some samples, it has been observed that many of the particles larger than 100 micrometers are fibres. However, APC's size particles based on projected area rather than longest dimension and do not differentiate between fibres and particles. Therefore, fibres will be reported as particles with dimensions considerably less than the length of the fibres. A problem with fibres 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.

DETERMINING AS4059E 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 (page 10) 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, or an optical or electron microscope. The size ranges measured and reported should be determined from Table 1 based on the measurement method.

DETERMINING AS4059E 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 (page 10).
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
b. Total number of particles larger than a specific size
c. Designating a class for each size range

DESIGNATING A CLASS FOR EACH SIZE RANGE

APC's 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: 38.924 per 100 ml / 3.38 fl oz
Size C: 3462 per 100 ml / 3.38 fl oz
Size D: 306 per 100 ml / 3.38 fl oz

(*) Please check standard for definition of size/classes

DETERMINING AS4059F 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 (page 11) 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, or an optical or electron microscope. The size ranges measured and reported should be determined from Table 1 based on the measurement method.

DETERMINING AS4059F 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 (page 11).
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
b. Total number of particles larger than a specific size
c. Designating a class for each size range

Sampling procedures are defined in ISO 4021. Extraction of fluid samples from lines of an operating system.
Receptacles should be cleaned in accordance with DIN/1505884.
The degree of cleanliness should be verified to ISO 3722.

PREFERRED METHODS

METHOD 1

Using a suitable sampling valve with PTFE seating method

- Install sampling valve in pressure or return line (in closed condition) at an appropriate point under constant flow or turbulent conditions
- Operate system for at least 30 minutes before taking a sample
- Clean outside of sampling valve
- Open the sampling valve to give appropriate flow rate and flush at least one litre of fluid through the valve **Do Not Close Valve After Flushing**

METHOD 2

Using an unspecified sampling valve

- Install valve in return line or an appropriate point where flow is constant and does not exceed 14 bar / 203 psi
- Operate system for at least 30 minutes before taking a sample
- Flush sampling valve by passing at least 45 litres / 11.89 U.S. Gal through valve back to reservoir
- Disconnect line from valve to reservoir with valve open and fluid flowing

- Remove cap from sampling bottle. Ensure cap is retained in hand face downwards
- Place bottle under sampling valve. Fill bottle to neck. Cap bottle & wipe.
- Close the sampling valve
- Label the bottle with the necessary information for analysis e.g. Oil type, running hours, system description etc.

METHODS OF TAKING SAMPLES FROM HYDRAULIC APPLICATIONS USING APPROPRIATE RECEPTACLES

RESERVOIR SAMPLING

METHOD 3

Use only if methods One & Two cannot be used

- Operate system for at least one hour before taking a sample
- Thoroughly clean area around the point of entry to the reservoir
- Attach sample bottle to the sampling device
- Carefully insert sampling hose into the midway point of the reservoir. Try not to touch sides or baffles within the reservoir
- Extract sample using the vacuum pump and fill to approx 75% volume
- Release vacuum, disconnect bottle and discard fluid
- **Repeat the above three steps three times to ensure flushing of the equipment**
- Attach ultra cleaned sample bottle to sampling device - collect final fluid sample
- Remove bottle from sampling device & cap - label with appropriate information

BOTTLE DIPPING

METHOD 4

Least preferred method due to possible high ingression of contamination

- Operate system for at least one hour before taking a sample
- Thoroughly clean area around the point of entry to the reservoir where sample bottle is to be inserted
- Clean outside of ultra clean sample bottle using filtered solvent, allow to evaporate dry
- Dip sample bottle into reservoir, cap and wipe
- Re-seal reservoir access
- Label the bottle with the necessary information for analysis e.g. Oil type, running hours, system description etc.

ENSURE THAT ALL DANGERS ARE ASSESSED AND THE NECESSARY PRECAUTIONS ARE TAKEN DURING THE SAMPLING PROCESS.

DISPOSAL OF FLUID SAMPLES MUST FOLLOW PROCEDURES RELATING TO COSHH AND OSHA GUIDELINES.

ATTENTION

NAS 1638
CLEANLINESS CLASSIFICATION STANDARD

The NAS system was originally developed in 1964 to define contamination classes for the contamination contained within aircraft components.
The application of this standard was extended to industrial hydraulic systems simply because nothing else existed at the time.
The coding system defines the maximum numbers permitted of 100 ml volume at various size intervals (differential counts) rather than using cumulative counts as in ISO 4406. Although there is no guidance given in the standard on how to quote the levels, most industrial users quote a single code which is the highest recorded in all sizes and this convention is used on MP Filtri APC's.
The contamination classes are defined by a number (from 00 to 12) which indicates the maximum number of particles per 100 ml, counted on a differential basis, in a given size bracket.

Size Range Classes (in microns)

Maximum Contamination Limits per 100 ml / 3.38 fl oz					
Class	**5 - 15**	**15 - 25**	**25 - 50**	**50 - 100**	**>100**
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

5 - 15 µm =	42 000 particles
15 - 25 µm =	2 200 particles
25 - 50 µm =	150 particles
50 - 100 µm=	18 particles
> 100 µm =	3 particles
Class NAS 8	

ISO 4405
GRAVIMETRIC LEVEL

The level of contamination is defined by checking the weight of particles collected by a laboratory membrane.
The membrane must be cleaned, dried and desiccated, with fluid and conditions defined by the Standard.
The volume of fluid is filtered through the membrane by using a suitable suction system. The weight of the contaminant is determined by checking the weight of the membrane before and after the fluid filtration.

CLEAN MEMBRANE

CONTAMINATED MEMBRANE

ISO 4406 CLEANLINESS CODE SYSTEM

The International Standards Organisation standard ISO 4406 is the preferred method of quoting the number of solid contaminant particles in a sample. The level of contamination is defined by counting the number of particles of certain dimensions per unit of volume of fluid. The measurement is performed by Automatic Particle Counters (APCs Automatic Particle Counter or PCMs Particle Contamination Monitor).

The numbers represent a code which identifies the number of particles of certain sizes in 1ml of fluid. Each code number has a particular size range.

The first scale number represents the number of particles equal to or larger than 4 $\mu m_{(c)}$ per millilitre of fluid;

The second scale number represents the number of particles equal to or larger than 6 $\mu m_{(c)}$ per millilitre of fluid;

The third scale number represents the number of particles equal to or larger than 14 $\mu m_{(c)}$ per millilitre of fluid.

Table 5 ISO 4406 - Allocation of Scale Numbers

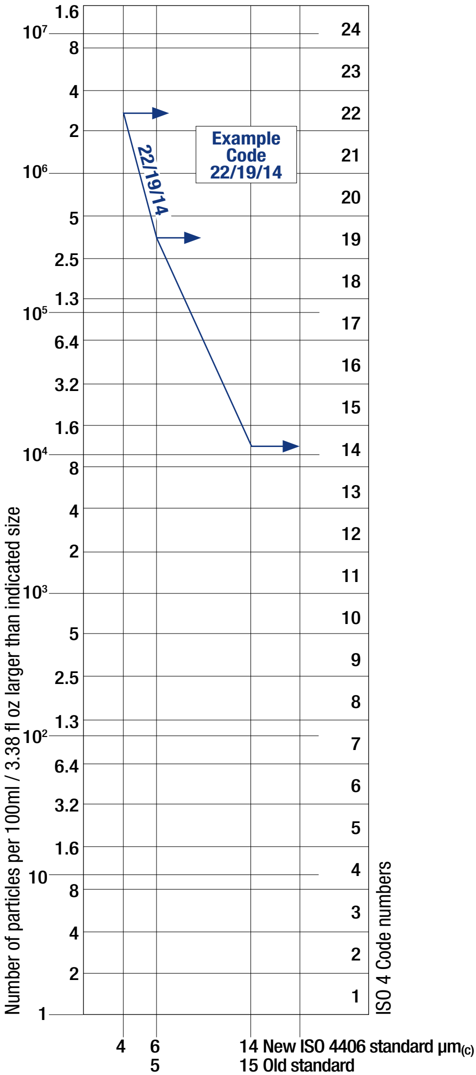
Class	Number of particles per ml / fl oz	
	Over	Up to
28	1 300 000	2 500 000
27	640 000	1 300 000
26	320 000	640 000
25	160 000	320 000
24	80 000	160 000
23	40 000	80 000
22	20 000	40 000
21	10 000	20 000
20	5 000	10 000
19	2 500	5 000
18	1 300	2 500
17	640	1 300
16	320	640
15	160	320
14	80	160
13	40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

≥ 4 $\mu m_{(c)}$ = 350 particles
≥ 6 $\mu m_{(c)}$ = 100 particles
≥ 14 $\mu m_{(c)}$ = 25 particles

> 16 / 14 / 12

Microscope counting examines the particles differently to APCs and the code is given with two scale numbers only. These are at 5 µm and 15 µm equivalent to the 6 $\mu m_{(c)}$ and 14 $\mu m_{(c)}$ of APCs.

Cleanliness Code Chart
with 100 ml / 3.38 fl oz sample volume



CLEANLINESS REPORTING FORMATS

SAE AS4059 - REV. E

CLEANLINESS CLASSIFICATION FOR HYDRAULIC FLUIDS (SAE AEROSPACE STANDARD)

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. Tables 1 and 2 below provide differential and cumulative particle counts respectively for counts obtained by an automatic particle counter, e.g. LPA3.

Class for differential measurement Table 1

Class	Dimension of contaminant Maximum Contamination Limits per 100 ml / 3.38 fl oz				
	6-14 µm(c)	14-21 µm(c)	21-38 µm(c)	38-70 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

6 - 14 µm(c) = 15 000 particles
14 - 21 µm(c) = 2 200 particles
21 - 38 µm(c) = 200 particles
38 - 70 µm(c) = 35 particles
> 70 µm(c) = 3 particles
SAE AS4059 REV E - Class 6

Class for cumulative measurement Table 2

Class	Dimension of contaminant Maximum Contamination Limits per 100 ml / 3.38 fl oz					
	>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	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

> 4 µm(c) = 45 000 particles
> 6 µm(c) = 15 000 particles
> 14 µm(c) = 1 500 particles
> 21 µm(c) = 250 particles
> 38 µm(c) = 15 particles
> 70 µm(c) = 3 particle
SAE AS4059 REV E
6A/6B/5C/5D/4E/2F

The information reproduced on this and the next page is a brief extract from SAE AS4059 Rev.E, revised in May 2005.
For further details and explanations refer to the full Standard.

SAE AS4059 - REV. F

CLEANLINESS CLASSIFICATION FOR HYDRAULIC FLUIDS (SAE AEROSPACE STANDARD)

Class for differential measurement

Table 1

Class	Dimension of contaminant Maximum Contamination Limits per 100 ml / 3.38 fl oz					(3)
	5-15 µm	15-25 µm	25-50 µm	50-100 µm	>100 µm	(1)
	6-14 µm(c)	14-21 µm(c)	21-38 µm(c)	38-70 µm(c)	>70 µm(c)	(2)
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	

6 - 14 µm(c) = 15 000 particles
14 - 21 µm(c) = 2 200 particles
21 - 38 µm(c) = 200 particles
38 - 70 µm(c) = 35 particles
> 70 µm(c) = 3 particles
SAE AS4059 REV F - Class 6

(1) Size range, microscope particle counts, based on longest dimension as measured per AS598 or ISO 4407.
(2) Size range, APC 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 NAS 1638.

Class for cumulative measurement

Table 2

Class	Dimension of contaminant Maximum Contamination Limits per 100 ml / 3.38 fl oz						
	>1 µm	>5 µm	>15 µm	>25 µm	>50 µm	>100 µm	(1)
	>4 µm(c)	>6 µm(c)	>14 µm(c)	>21 µm(c)	>38 µm(c)	>70 µm(c)	(2)
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	

> 4 µm(c) = 45 000 particles
> 6 µm(c) = 15 000 particles
> 14 µm(c) = 1 500 particles
> 21 µm(c) = 250 particles
> 38 µm(c) = 15 particles
> 70 µm(c) = 3 particle
SAE AS4059 REV F
cpc* Class 6 6/6/5/5/4/2

* cumulative particle count

(1) Size range, optical microscope, based on longest dimension as measured per AS598 or ISO 4407.
(2) Size range, APC calibrated per ISO 11171 or an optical or electron microscope with image analysis software, based on projected area equivalent diameter.

CONTAMINANT SIZES

ISO 4407

CUMULATIVE DISTRIBUTION OF THE PARTICLES SIZE

The level of contamination is defined by counting the number of particles collected by a laboratory membrane per unit of fluid volume. The measurement is done by a microscope.
The membrane must be cleaned, dried and desiccated, with fluid and conditions defined by the Standard.
The fluid volume is filtered through the membrane, using a suitable suction system.
The level of contamination is identified by dividing the membrane into a predefined number of areas and by counting the contaminant particles using a suitable laboratory microscope.

MICROSCOPE CONTROL AND MEASUREMENT

Substance	Microns	
	from	to
BEACH SAND	100	2.000
LIMESTONE DUST	10	1.000
CARBON BLACK	5	500
HUMAN HAIR (diameter)	40	150
CARBON DUST	1	100
CEMENT DUST	3	100
TALC DUST	5	60
BACTERIA	3	30
PIGMENTS	0.1	7
TOBACCO SMOKE	0.01	1

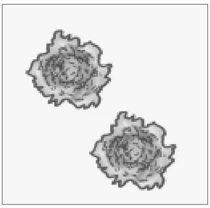
MICRON RATING SIZE COMPARISONS

1 Micron* = 0.001 mm

25.4 Micron* = 0.001 inch

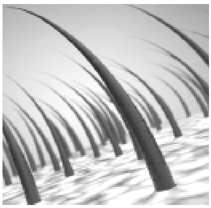
For all practical purposes particles of 1 micron size and smaller are permanently suspended in air.

100 µm



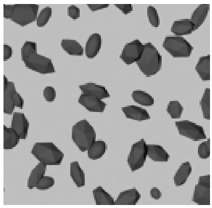
DUST PARTICLE
(dead skin)

75 µm



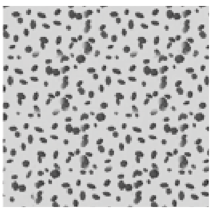
HUMAN HAIR

40 µm



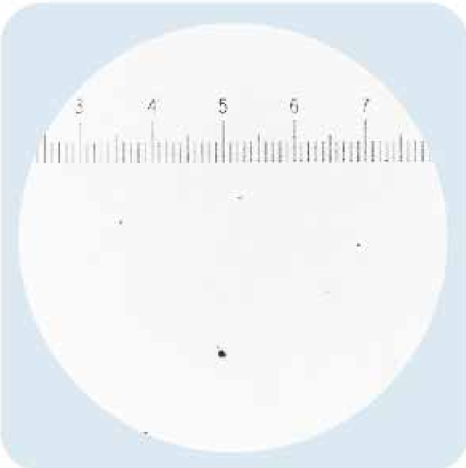
MINIMUM DIMENSION
VISIBLE WITH HUMAN EYES

4 - 14 µm

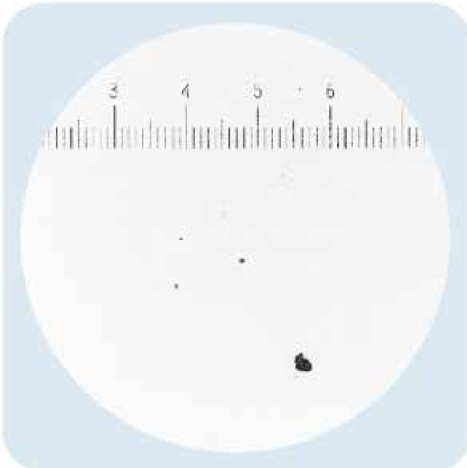


TYPICAL CONTAMINANT DIMENSION IN A HYDRAULIC CIRCUIT

* correct designation = Micrometre

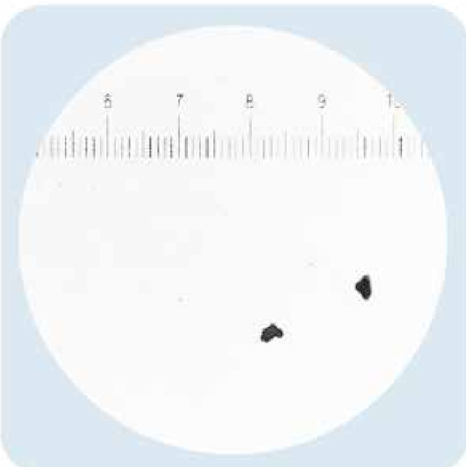


ISO 4406	Class 14/12/9
SAE AS4059E Table 1	Class 3
NAS 1638	Class 3
SAE AS4059E Table 2	Class 4A/3B/3C

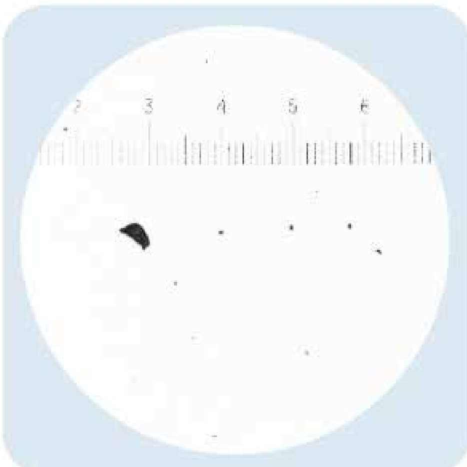


ISO 4406	Class 15/13/10
SAE AS4059E Table 1	Class 4
NAS 1638	Class 4
SAE AS4059E Table 2	Class 5A/4B/4C

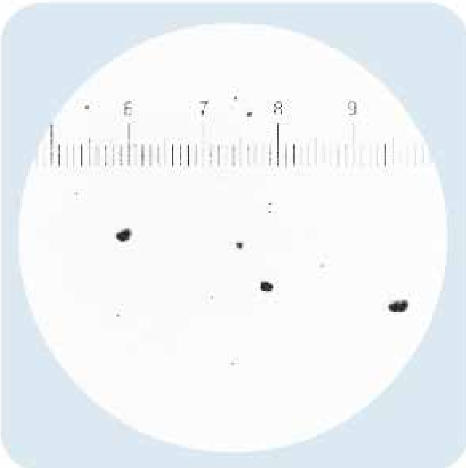
1 graduation = 10 µm



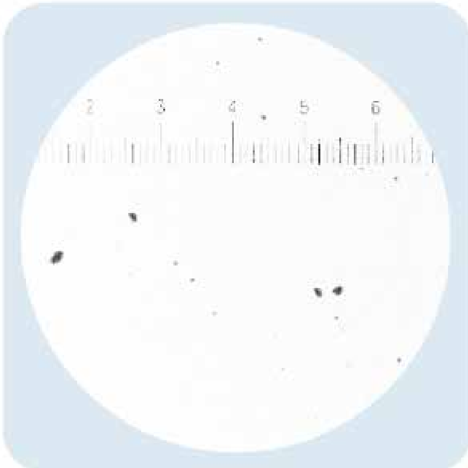
ISO 4406	Class 16/14/11
SAE AS4059E Table 1	Class 5
NAS 1638	Class 5
SAE AS4059E Table 2	Class 6A/5B/5C



ISO 4406	Class 17/15/12
SAE AS4059E Table 1	Class 6
NAS 1638	Class 6
SAE AS4059E Table 2	Class 7A/6B/6C

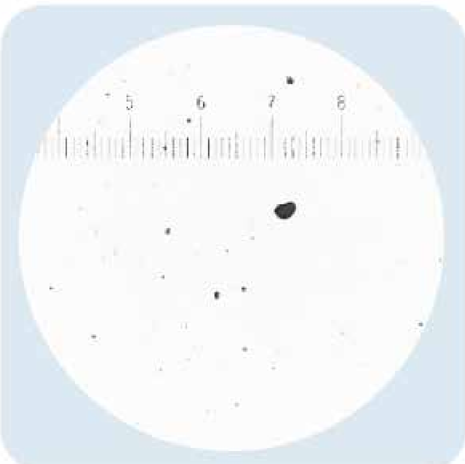


ISO 4406	Class 18/16/13
SAE AS4059E Table 1	Class 7
NAS 1638	Class 7
SAE AS4059E Table 2	Class 8A/7B/7C

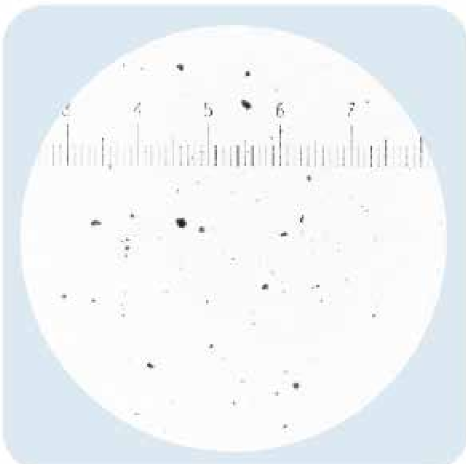


ISO 4406	Class 19/17/14
SAE AS4059E Table 1	Class 8
NAS 1638	Class 8
SAE AS4059E Table 2	Class 9A/8B/8C

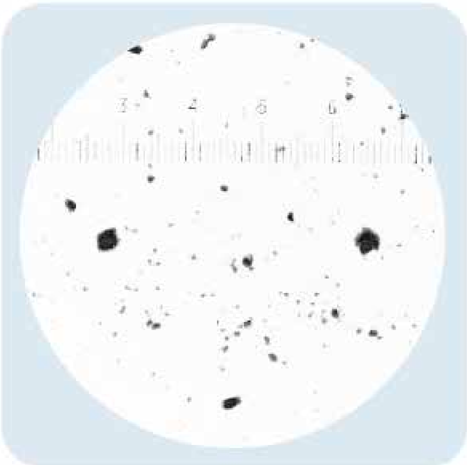
1 graduation = 10 µm



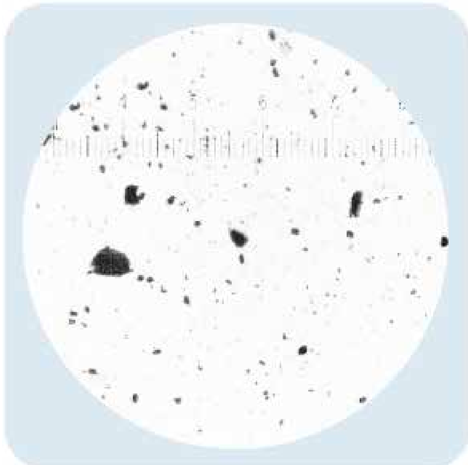
ISO 4406	Class 20/18/15
SAE AS4059E Table 1	Class 9
NAS 1638	Class 9
SAE AS4059E Table 2	Class 10A/9B/9C



ISO 4406	Class 21/19/16
SAE AS4059E Table 1	Class 10
NAS 1638	Class 10
SAE AS4059E Table 2	Class 11A/10B/10C



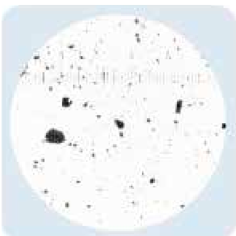
ISO 4406	Class 22/20/17
SAE AS4059E Table 1	Class 11
NAS 1638	Class 11
SAE AS4059E Table 2	Class 12A/11B/11C



ISO 4406	Class 23/21/18
SAE AS4059E Table 1	Class 12
NAS 1638	Class 12
SAE AS4059E Table 2	Class 13A/12B/12C

1 graduation = 10 µm

CONTAMINATION CLASSES

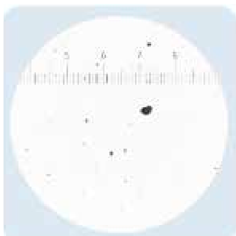


NAS 12
ISO 23/21/18

Typically New Oil as delivered in new certified mild steel 205 ltr barrels

NAS 7
ISO 18/15/13

Typically New Oil as delivered in new certified mini containers



NAS 9
ISO 21/18/15

Typically New Oil as delivered in oil tankers

NAS 6
ISO 17/15/12

Typically Required for most modern hydraulic systems

RECOMMENDED CONTAMINATION CLASSES

HYDRAULIC COMPONENT MANUFACTURER RECOMMENDATIONS

Most component manufacturers know the proportionate effect that increased dirt level has on the performance of their components and issue maximum permissible contamination levels. They state that operating components on fluids which are cleaner than those stated will increase life.

However, the diversity of hydraulic systems in terms of pressure, duty cycles, environments, lubrication required, contaminant types, etc, makes it almost impossible to predict the components service life over and above that which can be reasonably expected.

Furthermore, without the benefits of significant research material and the existence of standard contaminant sensitivity tests, **manufacturers who publish recommendations that are cleaner than competitors may be viewed as having a more sensitive product**.

Hence there may be a possible source of conflicting information when comparing cleanliness levels recommended from different sources.

The table gives a selection of maximum contamination levels that are typically issued by component manufacturer. These relate to the use of the correct viscosity mineral fluid. An even cleaner level may be needed if the operation is severe, such as high frequency fluctuations in loading, high temperature or high failure risk.

Example of recommended contamination levels for pressures below 140 bar - 2031 psi

Piston pumps with fixed flow rate	•					
Piston pumps with variable flow rate			•			
Vane pumps with fixed flow rate		•				
Vane pumps with variable flow			•			
Engines	•					
Hydraulic cylinders	•					
Actuators					•	
Test benches						•
Check valve	•					
Directional valves	•					
Flow regulating valves	•					
Proportional valves				•		
Servo-valves					•	
Flat bearings			•			
Ball bearings				•		
ISO 4406 CODE	20/18/15	19/17/14	18/16/13	17/15/12	16/14/11	15/13/10
Recommended filtration $\beta_{x(c)} \geq 1.000$	$\beta_{21(c)}$ >1000	$\beta_{15(c)}$ >1000	$\beta_{10(c)}$ >1000	$\beta_{7(c)}$ >1000	$\beta_{7(c)}$ >1000	$\beta_{5(c)}$ >1000
MP Filtri media code	A25	A16	A10	A06	A06	A03

HYDRAULIC SYSTEM TARGET CLEANLINESS LEVELS

Where a hydraulic system user has been able to check cleanliness levels over a considerable period, the acceptability, or otherwise, of those levels can be verified. Thus if no failures have occurred, the average level measured may well be one which could be made a bench mark.
However, such a level may have to be modified if the conditions change, or if specific contaminant-sensitive components are added to the system. The demand for greater reliability may also necessitate an improved cleanliness level.

The level of acceptability depends on three features:
- the contamination sensitivity of the components
- the operational conditions of the system
- the required reliability and life expectancy

Contamination codes ISO 4406			Correspondent codes NAS 1638	Recommended filtration degree	Typical applications
> 4 µm(c)	> 6 µm(c)	14 µm(c)		$\beta_{x(c)} \geq 1.000$	
14	12	9	3	3	High precision and laboratory servo-systems
17	15	11	6	3 - 6	Robotic and servo-systems
18	16	13	7	10 - 12	Very sensitive High reliability systems
20	18	14	9	12 - 15	Sensitive Reliable systems
21	19	16	10	15 - 25	General equipment of limited reliability
23	21	18	12	25 - 40	Low-pressure equipment not in continuous service

STANDARDS CLEANLINESS CODE COMPARISON

Although ISO 4406 standard is being used extensively within the hydraulics industry other standards are occasionally required and a comparison may be requested. The table below gives a very general comparison but often no direct comparison is possible due to the different classes and sizes involved.

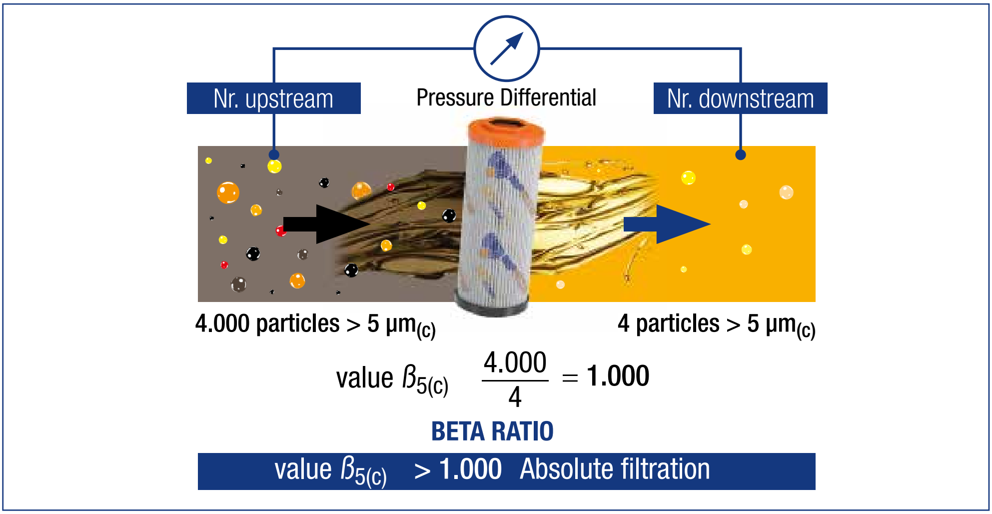
ISO 4406	SAE AS4059 Table 2	SAE AS4059 Table 1	NAS 1638
> 4 µm(c) > 6 µm(c) 14 µm(c)	> 4 µm(c) > 6 µm(c) 14 µm(c)	4-6 6-14 14-21 21-38 38-70 >70	5-15 15-25 25-50 50-100 >100
23 / 21 / 18	13A / 12B / 12C	12	12
22 / 20 / 17	12A / 11B / 11C	11	11
21 / 19 / 16	11A / 10B / 10C	10	10
20 / 18 / 15	10A / 9B / 9C	9	9
19 / 17 / 14	9A / 8B / 8C	8	8
18 / 16 / 13	8A / 7B / 7C	7	7
17 / 15 / 12	7A / 6B / 6C	6	6
16 / 14 / 11	6A / 5B / 5C	5	5
15 / 13 / 10	5A / 4B / 4C	4	4
14 / 12 / 9	4A / 3B / 3C	3	3

FILTER ELEMENT BETA RATIO INFORMATION

FILTER BETA RATIOS

The Beta Ratio equals the ratio of the number of particles of a maximum given size upstream of the filter to the number of particles of the same size and larger found downstream. Simply put, the higher the Beta Ratio the higher the capture efficiency of the filter.

Beta Ratio



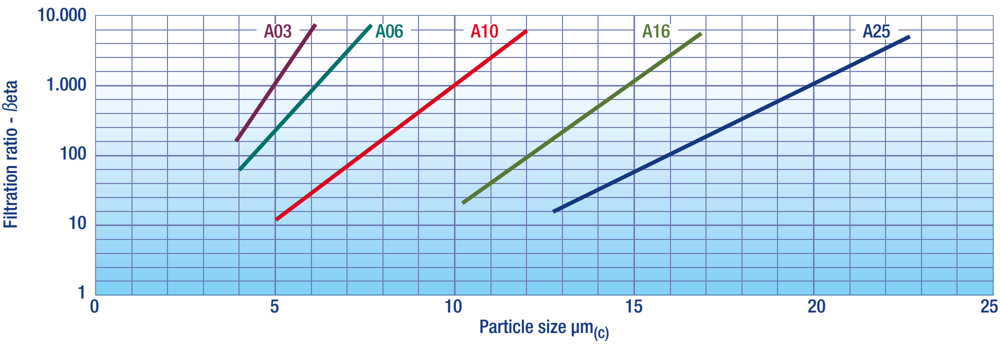
Filtration efficiency - Beta Ratio

Beta	2	10	50	75	100	200	1000	2000
%	50	90	98	98.7	99	99.5	99.9	99.95

Filtration ISO standard comparison

MP FILTRI FILTRATION GRADE	ISO 4572 $\beta_x > 200$	ISO 16889 $\beta_{x(c)} > 1000$
A03	3 µm	5 µm(c)
A06	6 µm	7 µm(c)
A10	10 µm	10 µm(c)
A16	18 µm	15 µm(c)
A25	25 µm	21 µm(c)

Filtration grade - Beta Ratio



TECHNICAL INFORMATIONS

The flow of fluids (either laminar or turbulent) is determined by evaluating the Reynolds number of the flow. The Reynolds number, based on studies of Osborn Reynolds, is a dimensionless number comprised of the physical characteristics of the flow.

For practical purposes, if the Reynolds number is less than 2000, the flow is laminar. If it is greater than 3500, the flow is turbulent. Flows with Reynolds numbers between 2000 and 3500 are sometimes referred to as transitional flows.

In practice for hydraulic/lubrication systems turbulent flow is achieved when the Reynolds number is greater than 4000 (Re > 4000).

Reynolds number is given by (Re) = 21220 x $\frac{Q}{di \times V}$

Where:
Q = Volumetric Flow Rate (litres/min - gpm)
di = Inside diameter or equivalent diameter of largest flow gallery (mm/in)
v = Viscosity of the flushing fluid at normal flushing temperature (Cst)

FLUSHING INFORMATION FOR VARIOUS PIPE DIAMETERS

Component cleaning/flushing systems can only be effective if Turbulent Flow is achieved.
The following guideline is with a fluid having a 86 kg/m^3 / 0.718 lb/gal fluid density (typical mineral oils) and 30 cSt viscosity.

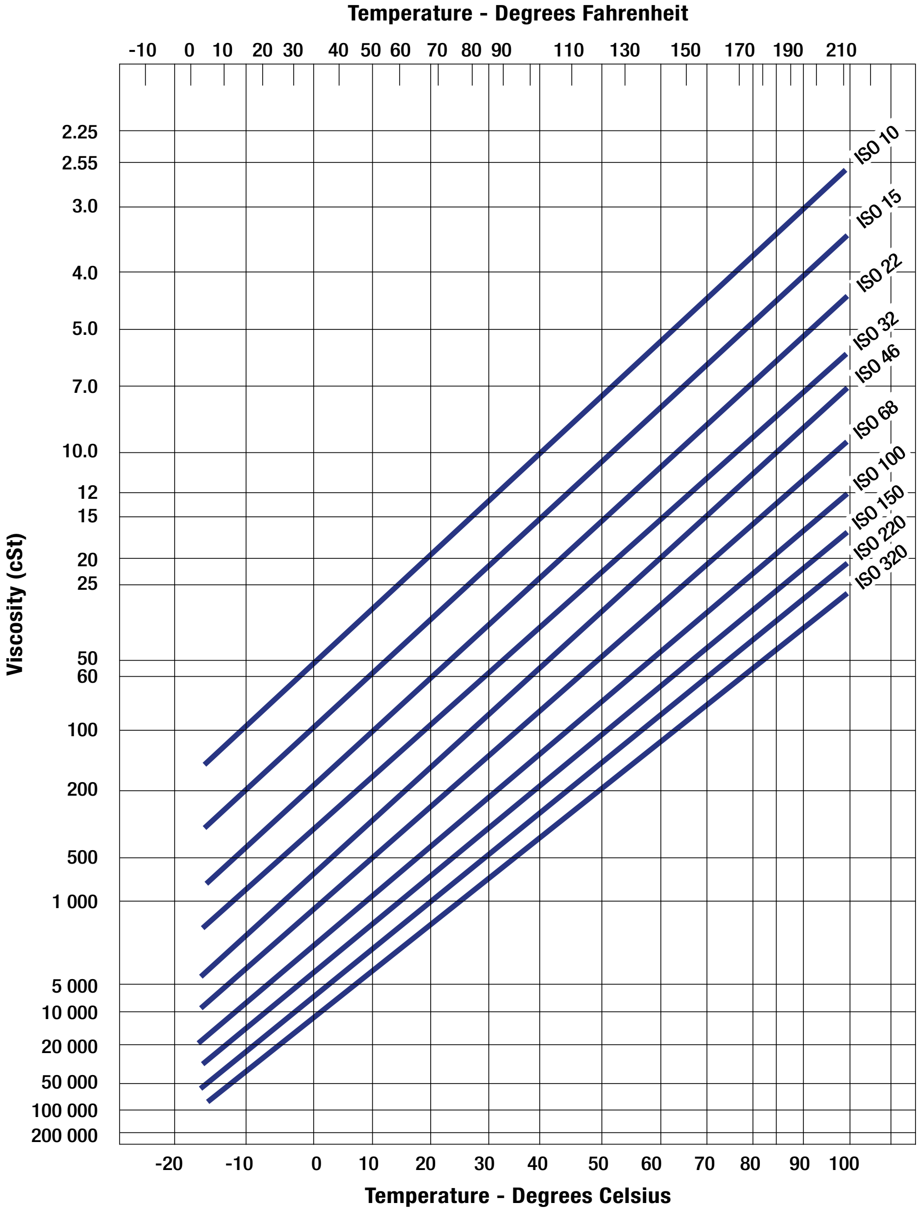
Nominal pipe size	Core		Flow for Re = 4000	
	[in]	[mm]	[l/min]	[gpm]
1/4"	0.451	11.5	65	17.17
1/2"	0.734	18.6	105	27.74
1"	1.193	30.3	171	45.17
1 1/4"	1.534	39.0	220	58.12
1 1/2"	1.766	44.9	254	67.10
2"	2.231	56.7	320	84.54

VISCOSITY CONVERSION CHART

STD grades against temperature

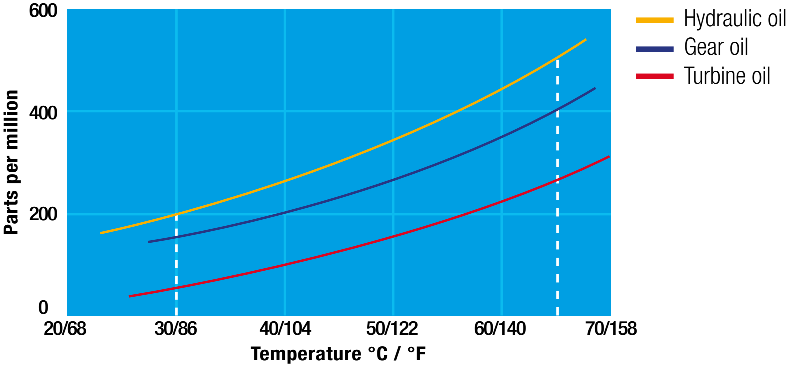
Oil viscosity / Temperature chart

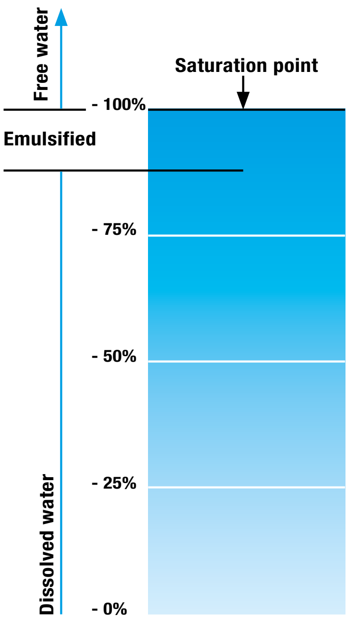
Lines shown indicates oils ISO grade Viscosity index of 100.
Lower V.I. oils will have a steeper slope.
Higher V.I. oils will have a flatter slope.



WATER CONTENT

In mineral oils and non aqueous resistant fluids water is undesirable. Mineral oil usually has a water content of 50-500 ppm (@40°C / 104°F) which it can support without adverse consequences. Once the water content exceeds about 500 ppm the oil starts to appear hazy. Above this level there is a danger of free water accumulating in the system in areas of low flow. This can lead to corrosion and accelerated wear.
Similarly, fire resistant fluids have a natural water which may be different to mineral oil.





Saturation levels

Since the effects of free (also emulsified) water is more harmful than those of dissolved water, water levels should remain well below the saturation point.

However, even water in solution can cause damage and therefore every
reasonable effort should be made to keep saturation levels as low as possible.
There is no such thing as too little water. As a guideline, we recommend maintaining saturation levels below 50% in all equipment.

TYPICAL WATER SATURATION LEVEL FOR NEW OILS
Examples:
Hydraulic oil @ 30°C / 86°F = 200 ppm = 100% saturation
Hydraulic oil @ 65°C / 149 °F = 500 ppm = 100% saturation

WATER ABSORBER

Water is present everywhere, during storage, handling and servicing.

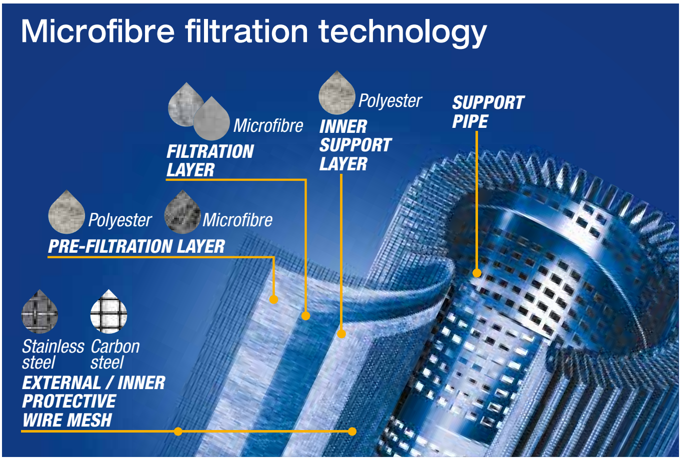
MP Filtri filter elements feature an absorbent media which protects hydraulic systems from both particulate and water contamination.
MP Filtri's filter element technology is available with inorganic microfiber media with a filtration rating 25µm (therefore identified with media designation WA025, providing absolute filtration of solid particles to $\beta_{x(c)} = 1000$.
Absorbent media is made by water absorbent fibres which increase in size during the absorption process.
Free water is thus bonded to the filter media and completely removed from the system (it cannot even be squeezed out).

FILTER MEDIA

Fabric that absorbs water

ABSORBER MEDIA LAYER

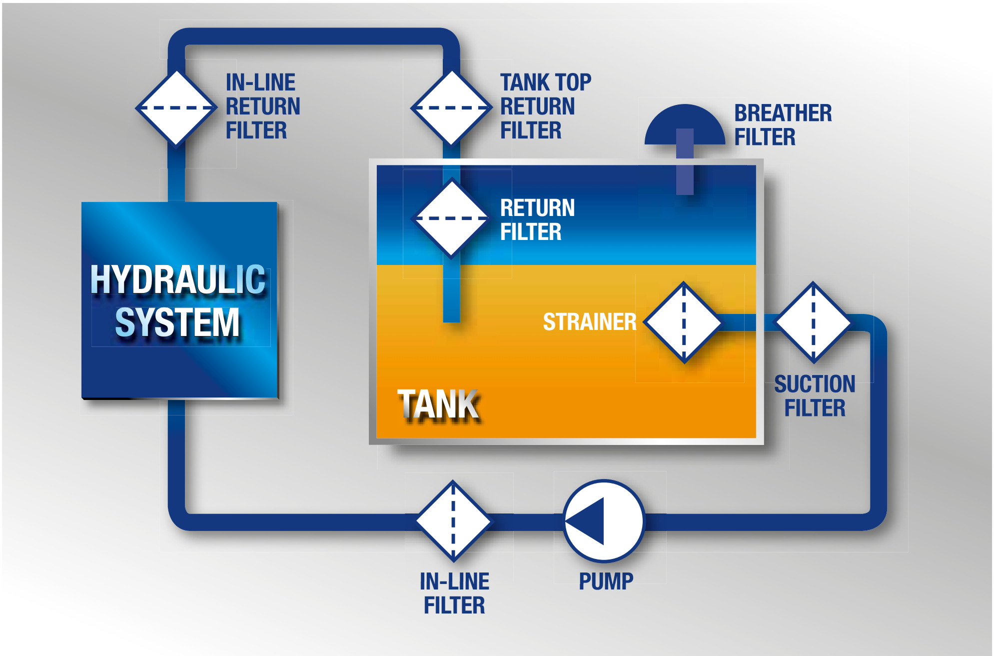
The Filter Media has absorbed water



By removing water from your fluid power system, you can prevent such key problems as:
- corrosion (metal etching)
- loss of lubricant power
- accelerated abrasive wear in hydraulic components
- valve-locking
- bearing fatigue
- viscosity variance (reduction in lubricating properties)
- additive precipitation and oil oxidation
- increase in acidity level
- increased electrical conductivity (loss of dielectric strength)
- slow/weak response of control systems

EVALUATION OF DIFFERENTIAL PRESSURE VS. FLOW CHARACTERISTICS

Increasing pressure in a hydraulic system means
- **Increasing compressability of oil**
- **Increasing viscosity of oil**



Variation of viscosity due to the increasing of pressure

ISO VG (cSt)	Pressure [bar / psi]					
	bar	50	100	200	300	400
	psi	725	1450	2900	4350	5800
	Viscosity Increase (cSt)					
32		35	38	46	54	66
46		50	55	66	77	94
68		75	81	98	114	140
100		109	119	143	167	205
220		240	261	315	367	450
320		349	380	458	534	655

Maximum total pressure drop (Δp max) allowed by a new and clean filter

Application	Range [bar / psi]	
Suction filters	0.08 - 0.10 bar	
	1.16 - 1.45 psi	
Return filters	0.4 - 0.6 bar	
	5.80 - 8.70 psi	
Return - Suction filters (*)	0.8 - 1.0 bar	
	11.60 - 14.50 psi	
Low & Medium Pressure filters	0.4 - 0.6 bar	return lines
	5.80 - 8.70 psi	
	0.3 - 0.5 bar	lubrication lines
	4.35 - 7.25 psi	
	0.3 - 0.4 bar	off-line in power systems
	4.35 - 5.80 psi	
	0.1 - 0.3 bar	off-line in test benches
	1.45 - 4.35 psi	
	0.4 - 0.6 bar	over-boost
	5.80 - 8.7 psi	
High Pressure filters	0.8 - 1.5 bar	
	11.60 - 21.75 psi	
Stainless Steel filters	0.8 - 1.5 bar	
	11.60 - 21.75 psi	

(*) The suction flow rate should not exceed 30% of the return flow rate

EVALUATION OF DIFFERENTIAL PRESSURE VS. FLOW CHARACTERISTICS

FILTER SIZING

THE CORRECT FILTER SIZING HAVE TO BE BASED ON THE TOTAL PRESSURE DROP DEPENDING BY THE APPLICATION.
FOR EXAMPLE, THE MAXIMUM TOTAL PRESSURE DROP ALLOWED BY A NEW AND CLEAN RETURN FILTER HAVE TO BE IN THE RANGE 0.4 - 0.6 bar / 5.80 - 8.70 psi.

The pressure drop calculation is performed by adding together the value of the housing with the value of the filter element. The pressure drop Δpc of the housing is proportional to the fluid density (kg/dm^3 / lb/ft^3). The filter element pressure drop Δpe is proportional to its viscosity (mm^2/s / SUS), the corrective factor Y have to be used in case of an oil viscosity different than 30 mm^2/s (cSt) / 150 SUS.

Sizing data for single filter element, head at top

Δpc = Filter housing pressure drop [bar / psi]
Δpe = Filter element pressure drop [bar / psi]
Y = Corrective factor Y (see correspondent table), depending on the filter type, on the filter element size, on the filter element length and on the filter media
Q = flow rate (l/min - gpm)
V1 reference oil viscosity = 30 mm^2/s (cSt) /150 SUS
V2 = operating oil viscosity in mm^2/s (cSt) / SUS

Filter element pressure drop calculation with an oil viscosity different than 30 mm²/s (cSt) / 150 SUS

International system:
Δpe = Y : 1000 x Q x (V2:V1)

Imperial system:
Δpe = Y : 17.2 x Q x (V2:V1)

Δp Tot. = Δpc + Δpe

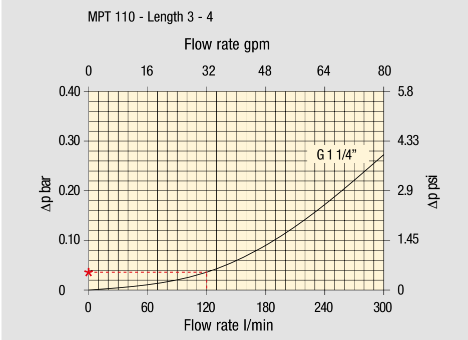
Verification formula

Δp Tot. ≤ Δp max allowed

Generic filter calculation example

Application data:
Tank top return filter
Pressure Pmax = 10 bar / 145.03 psi
Flow rate Q = 120 l/min / 31.7 gpm
Viscosity V2 = 46 mm^2/s (cSt) / 216 SUS
Oil density = 0.86 kg/dm^3 /53.68 lb/ft^3
Required filtration efficiency = 25 µm with abs. filtration
With bypass valve and G 1 1/4” inlet connection

Calculation:
Δpc = 0.03 bar / 0.43 psi (see graphic below)



Filter housings Δp pressure drop. The curves are plotted using mineral oil with density of 0.86 kg/dm^3 / 53.68 lb/ft^3
in compliance with ISO 3968. Δp varies proportionally with density.

Δpe = (2.00 : 1000) x 120 x (46 : 30) = 0.37 bar
Δpe = (2.00: 17.2) x 32 x (216 : 150) = 5.36 psi

Filter element		Absolute filtration H Series					Nominal filtration N Series		
Type		A03	A06	A10	A16	A25	P10	P25	M25 M60 M90
Return filters	1	28.20	24.40	8.67	8.17	6.88	4.62	3.96	1.25
	2	17.33	12.50	6.86	5.70	4.00	3.05	2.47	1.10
MF 100	3	10.25	9.00	3.65	3.33	2.50	1.63	1.32	0.96
MFX 100	4	6.10	5.40	2.30	2.20	2.00	1.19	0.96	0.82

Δp Tot. = 0.03 + 0.37 = 0.4 bar
Δp Tot. = 0.43 + 5.36 = 5.79 psi

The selection is correct because the total pressure drop value is inside the admissible range for top tank return filters.
In case the allowed max total pressure drop is not verified, it is necessary to repeat the calculation changing the filter length/size.

The culmination of a multi-million Euro investment in technology and a long-standing intellectual collaboration with some of Italy's leading scientific institutions, MP Filtri's new state-of-the-art Research and Development Faciity has been established as a hub of technical **excellence and innovation.**
Based in Pessano con Bornago, Milan, the 1.200 m^2 / 12.917 ft^2 scientific research facility places a sharp focus on practical industrial applications. It has been created to spearhead the development of an innovative range of market-leading products; enhance the quality and reliability of the existing portfolio, and support the creation of customer-driven prototype designs.
MP Filtri's dedication to excellence in scientific research has been built on the close partnerships it has established with the Polytechnic of Milan, the University of Bologna and the University of Modena and Reggio Emilia.

Far more than just a test lab, facilities include: specialist training areas, comfortable meeting rooms and study areas - enabling customers to combine academic and theoretical training with hands-on practical work on state-of-the-art test benches.
This creates perfect opportunities for mastering how the equipment works in tackling fluid contamination; boosting the knowledge and expertise of delegates; and gaining experience in a realistic working environment.

The 'heart' of the lab is the test bench facility which has been specially designed to validate the operating characteristics and performance of elements and filters. These advanced work stations offer pinpoint accuracy in measuring the level of contamination from solid particles in oils under pressure.
All tests are carried out in accordance with international standards and reproduce the precise conditions of the pressure and flow of any hydraulic circuit inside controlled and filtered climate chambers.

- 16 test benches
- 8 laboratory equipment for analysing contamination
- 15 ISO and DIN International Standard
- 29 different tests

Per year:

- More than 200 tests requested
- More than 1500 tested components
- More than 90 Multi-pass tests

NOTES

NOTES

NOTES

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