Filtration guidelines

Cleanliness of hydraulic fluid is a priority aspect in the design of all hydraulic systems as approximately 80% of failures are caused by the presence of solid contamination.

The solid contamination cannot be completely removed, but it can be consistently reduced and controlled by means of hydraulic filters (in line and return line type, see section 2) so that the quantity and dimensions of particles present into the fluid (contamination class) are acceptable for the specific type of system.

The purpose of this document is to provide information on the different types of filters and suggestions for their correct use. Through an optimized filtration system it is possible to obtain appropriate fluid cleanliness and thus reduce the damages caused by contamination, extending the life of the machines and preventing production downtime.

1 RECOMMENDED CONTAMINATION CLASSES

The **recommended fluid contamination class** is the max level of contamination acceptable for a certain hydraulic system and it depends to the filtration system architecture.

The fluid contamination class must be evaluated taking into account several parameters as:

- type of hydraulic components installed in the system: the required cleanliness level has to be determined according to the most sensitive component, i.e. presence of servoproportional valves
- type of application and surrounding environment: particular dusty environments , i.e. ceramic presses, require specific filtration circuits and methods to prevent that the solid contamination enters the system tank (pressurized tank)
- duty cycle: heavy duties and high pressure values require better contamination classes
- expected system lifetime
- typical operation and start-up temperatures

The fluid contamination level of a specific hydraulic system corresponds to the contaminant level measured in the tank.

The following table provides the suggested contamination classes, depending on the hydraulic components and their expected operating life.

The contamination class has to be selected according to the most sensitive component installed in the system.

Standard	**Typical contamination classes**						
ISO 4406	15/13/10	16/14/11	17/15/12	18/16/13	19/17/14	20/18/15	21/19/16
NAS 1638	4	5	6	7	8	9	10
SAE 5049	5A/4B/4C	6A/5B/5C	7A/6B/6C	8A/7B/7C	9A/8B/8C	10A/9B/9C	11A/10B/10C
Recommend filter element	F03	F03 F06	F06	F06 F10	F10 F20	F20 F25	
Component							
Proportional valves		longer life		normal operation			
Solenoid & conventional valves					longer life	normal operation	
Variable displacement pumps				longer life		normal operation	
Fixed displacement pumps					longer life		normal operation
Cylinders					longer life	normal operation	

2 HYDRAULIC FILTERS TYPE

The architecture of a filtration system involves the use of different type of hydraulic filters with specific characteristics; typically they are “in line” and “return line” filters.

The type of fluid used in the hydraulic system influences the choice of filter.

It is always recommended to verify the compatibility of the fluid characteristics with the selected filter.

2.1 In line filters

FPS

In line filters are normally installed in the system main line, immediately after the pump or before valve’s manifold, in order to protect all downstream components from contamination.
They have to be sized in accordance with the maximum system pressure and flow rate.
Atos in line filters **FPS** (threaded ports) and **FPH** (SAE 6000 flanged ports) are suitable for max operating pressure up to 420 bar.

In line filters are provided with or without by-pass valve:

- filters with by-pass valve are used to permit the flow passage in case of clogged filtering element. This is an extreme condition to be always avoided by a correct maintenance
- filters without by-pass valves are used to protect critical components like servoproportional valves; in this execution the filter element can withstand a higher differential pressure (collapse pressure)

In line filters can be provided with a clogging indicator, notifying the status of the filter element and allowing its replacement before the filter by-pass opening (if present), see section 6.

FPH

2.2 Return line filters

They perform the **filtration of the fluid returning back to the tank from the hydraulic circuit**, ensuring that all the contaminants generated by components wear do not enter the tank and will not be recirculated into the system.
They have to be sized considering the maximum flow on return line during the whole machine cycle; particularly, in case of differential cylinders the return flow could be greater than the pump flow.

Return line filters can be installed in line or on the top of the hydraulic tank and have to be selected considering return line pressure.
Atos return line filters type **FRS** are designed for tank top mounting and to withstand max operating pressure up to 8 bar.

Return line filters are provided with a by-pass valve to prevent dangerous excessive back-pressure in the return line caused by the clogged filer element.
The filter outlet must be always located below the fluid level, in all operating conditions, to prevent possible foaming of the fluid in the tank.

FRS

2.3 Suction filters

These filters are used to **protect the pump from ingestion of coarse contamination**. Atos suction filters type **FSS** are designed to be directly fit on the pumps suction line.
To avoid the risk of pump cavitation, suction filters are generously sized, with high filtration ratings and low differential pressures.
Suction filters have to be sized also considering cold start-up operations, because low oil temperatures could boost up cavitation phenomenon.

Due to cavitation reasons they are normally avoided for variable displacement piston pumps.

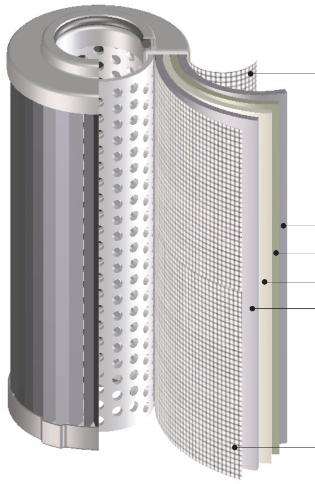
FSS

2.4 Filter elements

Atos **Filtration Plus** filter elements provide excellent performance in terms of efficiency (βeta Ratio > 1.000) and stability Vs. pressure drop increase.
Thanks to the special construction based on microfiber media, these elements are characterized by a very high Dirt Holding Capacity (DHC) - see section 4, up to 30% higher than other media packs.
The higher DHC combined with a lower pressure drop, contribute to significantly increase the operating life of the filter element, and therefore a reduction of maintenance costs.

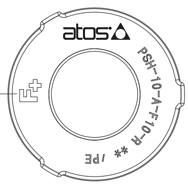
F+ Filtration Plus filter elements are available with standard filtration rating:
5µm, 7µm, 12µm, 22µm for in line filters type FPS and FPH
7µm, 12µm, 27µm for return line filter FRS
Filtration rating 4µm$_{(c)}$ is available on request for FPS and FPH filters for applications requiring extremely high fluid cleanliness.

F+ FILTRATION PLUS



PSH filter element

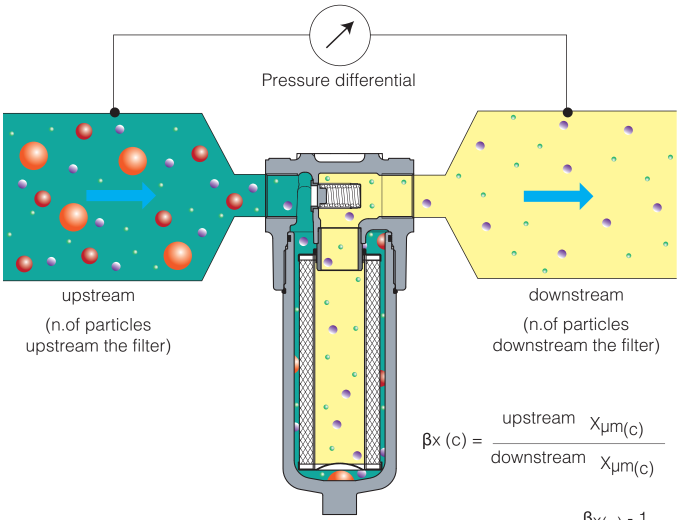
Filtration Plus identification



3 FILTER EFFICIENCY AND BETA RATIO

The filter efficiency is the capability of the filter to block a certain quantity of particles equal or greater than a defined dimension.
The most commonly used rating in the industry is the **Beta ratio** $\beta x\ (c)$, defined as the number of particles of a given size upstream the filter, divided by the number of particles of the same size counted downstream the filter. The higher the Beta Ratio, the higher is the filter efficiency.

n. of particles upstream the filter	n. of particles downstream the filter	Beta ratio $\beta x_{(c)}$	Efficiency %
1.000.000	500.000	2	50
	100.000	10	90
	50.000	20	95
	13.000	75	98,7
	5.000	200	99,5
	1.000	1.000	99,9



$$\beta x\ (c) = \frac{\text{upstream } X\mu m_{(c)}}{\text{downstream } X\mu m_{(c)}}$$

$$\text{Efficiency\%} = 100\ \frac{\beta x_{(c)} - 1}{\beta x_{(c)}}$$

3.1 Standards for Beta ratio determination

Since 1999 the **ISO16889** has been introduced as international standard to regulate the execution of Multi-Pass Tests to assess the Beta value of a filter element, replacing old ISO 4578.

ISO16889 considers the filter efficiency = 99,9% (β ratio > 1000), while for old ISO4572 the efficiency was lower = 99,5% (βratio > 200),

To avoid misunderstandings, particles measured to ISO16889 are identified as **$\mu m_{(c)}$**

The table below reports the Beta values of Atos filter elements, according to the considered standard.

Microfibre filter element	$\beta x_{(c)} > 1000$ (ISO16889)	$\beta x > 200$ (ISO4572)
F03	5 $\mu m_{(c)}$	3 µm
F06	7 $\mu m_{(c)}$	6 µm
F10	12 $\mu m_{(c)}$	10 µm
F20	22 $\mu m_{(c)}$	20 µm
F25	27 $\mu m_{(c)}$	25 µm

Cellulose filter element	$\beta x_{(c)} > 2$ (ISO16889)	$\beta x > 2$ (ISO4572)
C10	10 $\mu m_{(c)}$	10 µm
C25	25 $\mu m_{(c)}$	25 µm

Contamination classes and pressure drop values remain unchanged between ISO4572 and ISO16889

4 DIRT-HOLDING CAPACITY

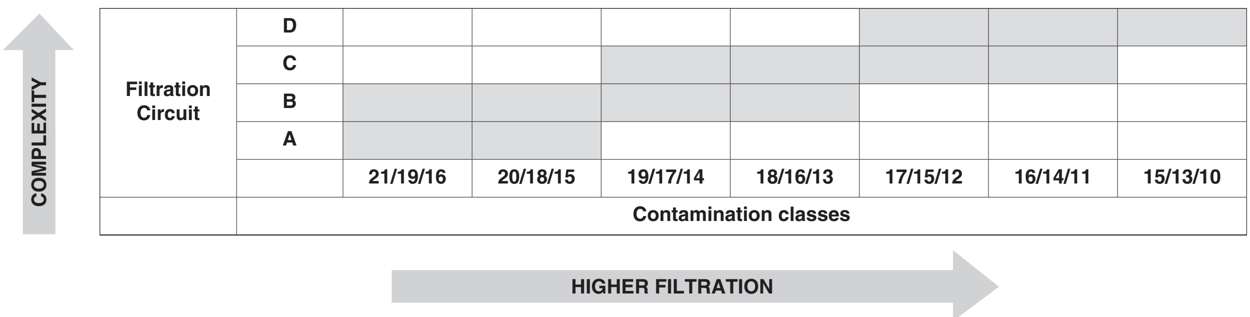
The Beta ratio does not give any indication about the total amount of contaminant that can be trapped by the filter during its life.

This parameter is defined **DIRT-HOLDING CAPACITY (DHC)** and it defines the quantity of contaminant that the filter element can trap and hold before the maximum allowable back pressure or delta P level is reached.
Generally, a filter element with a larger effective filtration surface has a greater dirty holding capacity and therefore a longer service life.

5 FILTRATION CIRCUIT

The solid contamination caused by normal component's wear is the main source of fluid contamination.
To avoid malfunctioning and progressive deterioration of the components installed in the hydraulic system, a proper filtration circuit has to be designed.

The following recommendations support the user in designing of an optimized filtration circuit.
The table below suggests the selection of a filtration circuit according to the targeted contamination class, see section 1 for recommended contamination classes.



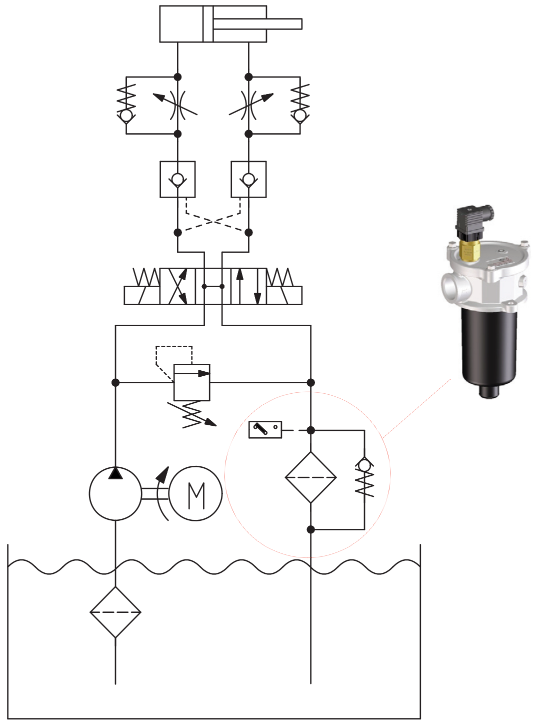
General rules to be followed to ensure optimal operating conditions for the hydraulic systems:
- the hydraulic tank has to be properly designed to limit the ingress of external contamination
- maintenance operations must be performed to avoid the ingress of contamination.

Consult Atos technical office for additional support for proper design of filtration circuits.

CIRCUIT A

Return line filter ensures that all the contaminants generated during system operations are correctly filtered before entering the tank.
It is a cost effective solution mainly used in systems with on-off valves.

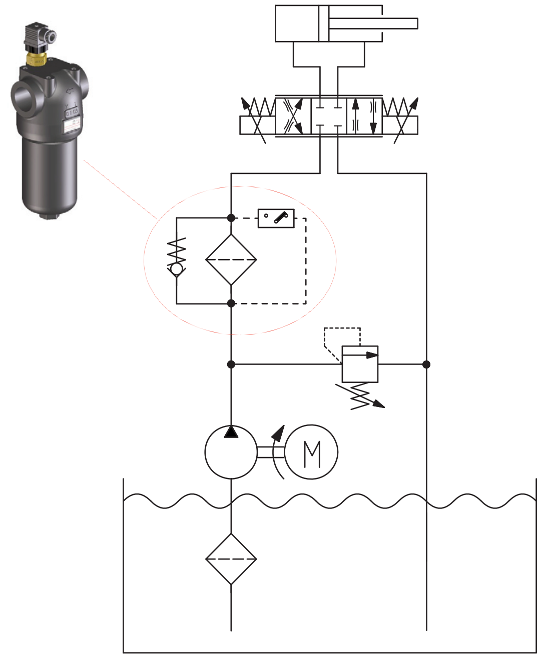
This configuration can't ensure protection of hydraulic components from wear generated by the pump.



CIRCUIT B

In line filter is normally installed immediately after the pump, to guarantee a correct filtration of the fluid before it reaches the hydraulic components.
It is a solution particularly used to protect proportional and servoproportional valves.

This configuration can't ensure protection of hydraulic components from contaminants generated further downstream and of the pump from dirt returned to the tank.

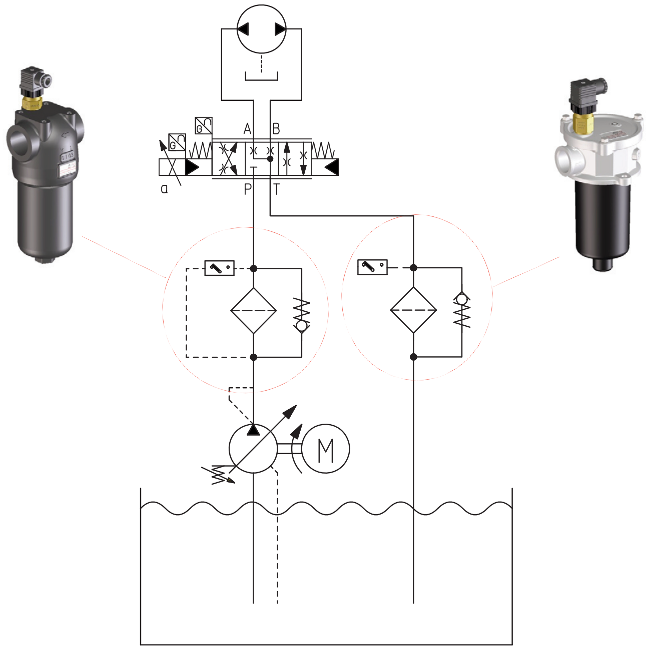


CIRCUIT C

This example shows a circuit with **both in line and return line filters.**
It is an ideal solution to enhance the whole system efficiency.

This system configuration will ensure:
- correct protection of components from wear generated by the pump
- correct filtration of the fluid flowing back to the tank, removing all the contamination entered in the system as consequence of components wear.

An efficient contamination control is guaranteed if the whole pump flow is passing through the filters.
As consequence, this system configuration is not indicated for circuits with variable displacement pumps operating for long time in null flow.

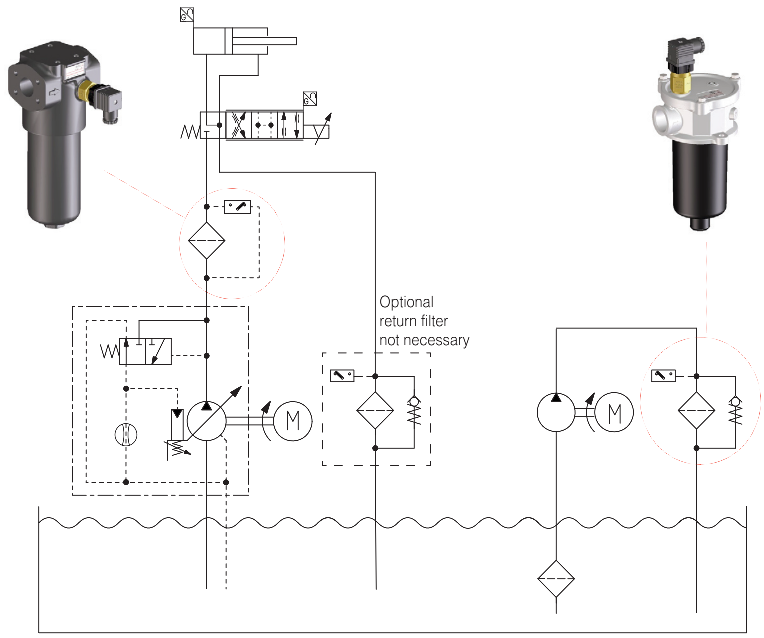


CIRCUIT D

This example is similar to circuit C but implemented with an **additional off-line filtration system.**
It is an ideal solution when wide change in system flow rates are expected or for systems equipped with variable displacement pumps operating for long time in null flow.
The additional off-line filtration system allows to maintain a constant filtration of the fluid in the tank, avoiding the accumulation of contamination particles

This system configuration will ensure:
- excellent cleanliness level, independently of the operating cycles of the main circuit
- higher dirt-holding capacity along with higher filtration efficiency
- easier maintenance operations thanks to the possibility of replacing the filter element without stopping the machine.

To protect critical components like servoproportional valves, in line filter without by-pass valves is suggested.



6 **CLOGGING INDICATORS**

They notify to the operator when the filter element is near to be clogged and then it must be replaced.
Their use is recommended for in line and return line filters to avoid that the high pressure caused by the clogged filter element causes the filter by-pass opening and the consequent release of contaminants into the hydraulic circuit.

Depending on the type of hydraulic filter, different clogging indicators are used:

- **Visual indicator**, Atos type **CIA-V**, normally used with **return line filters**
  It is a pressure gauge which measures the pressure before the filer element and indicates the clogged condition by means of coloured sectors:
  Green (range 0 to 3 bar) = filter element in good condition;
  Red (> 3) = filter element to be immediately replaced
  It requires a constant visual inspection by the operator to verify the filter condition

CIA-V

- **Electrical indicator**, Atos type **CIA-E**, normally used with **return line filters**
  It is a pressure switch which measures the pressure before the filer element and it indicates the clogged condition by means of switching contact (NO or NC)
  The switching pressure if factory set at 2 bar corresponding to 70% of the by-pass valve cracking pressure
  The electric contact is normally interfaced with the machine CNC for the automatic monitoring of the filter condition

CIA-E

- **Visual differential indicator**, Atos type **CID-V**, normally used with **in line filters**
  It is a pressure switch which measures the Δp across the filer element and it indicates the clogged condition by means of coloured bands:
  Green = filter element in good condition;
  Red = filter element to be immediately replaced
  The switching pressure if factory set at 5 bar corresponding to 80% of the by-pass valve cracking pressure
  For filters without by-pass valve the switching pressure if factory set at 8 bar
  It requires a constant visual inspection by the operator to verify the filter condition

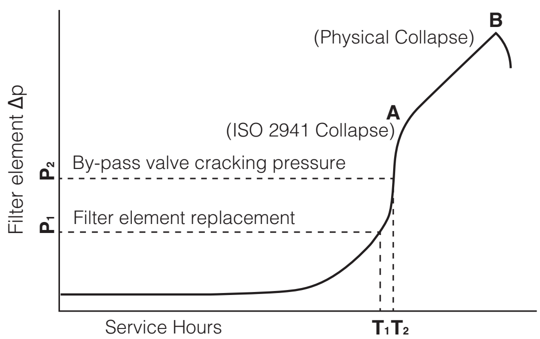
CID-V

- **Electrical differential indicator**, Atos type **CID-M**, normally used with **in line filters**
  It is a pressure switch which measures the Δp across the filer element and it indicates the clogged condition by means of switching contact (NO or NC)
  The switching pressure if factory set at 5 bar corresponding to 80% of the by-pass valve cracking pressure
  For filters without by-pass valve the switching pressure if factory set at 8 bar
  The electric contact is normally interfaced with the machine CNC for the automatic monitoring of the filter condition
  Optional version, Atos code **CID-L**, is provided with additional LED to indicate the filer clogged condition

CID-E

Notes about Electrical differential indicator function

The electrical differential clogging indicator switches at pressure P1, signalling the necessity to replace the filter element, before the by-pass valve cracking pressure P2.
To protect the system from contamination, the set value P1 of the clogging indicator is always lower than the cracking pressure P2 of the by-pass valve.
For in line filters without by-pass valve, the continued operation at higher Δp can cause the degradation of the filtration performances (point A in the diagram). In the worst case the filter element may collapse, losing its integrity (point B in the below diagram).
For this reason, in line filters without by-pass valves are usually provided with filter element having high collapse pressure value.



7 **ISO STANDARDS**

The following lists is intended to provide a documentation of the actual ISO norms relevant to hydraulic filtration

ISO 2941 Hydraulic fluid power – Filter element – verification of collapse/burst pressure rating

ISO 2942 Hydraulic fluid power – Filter element – verification of fabrication integrity and determination of the first bubble point

ISO 2943 Hydraulic fluid power – Filter element – verification of material compatibility with fluids

ISO 3723 Hydraulic fluid power – Filter element – method for end load test

ISO 3724 Hydraulic fluid power – Filter element – determination of resistance to flow fatigue using particulate contaminant

ISO 3968 Hydraulic fluid power – Filters – evaluation of differential pressure versus flow characteristics

ISO 4406 Hydraulic fluid power – Fluids – method for coding the level of contamination by solid

ISO 16889 Hydraulic fluid power – Filters – multi-pass method for evaluating filtration performance of a filter element

ISO 23181 Hydraulic fluid power – Filter element – determination of resistance to flow fatigue using high viscosity fluid

ISO 11170 Hydraulic fluid power – sequence of tests for verifying performance characteristics of filter elements

ISO 10771-1 Hydraulic fluid power – fatigue pressure testing of metal pressure-containing envelopes – test method