FILTRATION IN BRIEF

CONTAMINATION CONTROL

Contamination Control in the hydraulic system is a very wide and complex matter; the following is just a short summary.
Our Customer Service is available for any further information.
The function of the fluid in the hydraulic systems is transmitting power and motion.
For a reliable and efficient operating of the system, it is very important to select the fluid considering the requirements of the system and the specific working conditions (working pressure, operating temperature, location of the system, etc.).
Depending on the required features (viscosity, lubricant capacity, anti-wear protection, density, resistance to ageing and to thermal variations, materials compatibility, etc.), the proper oil can be selected among a number of mineral oils, synthetic fluids, water based fluids, environmental friendly fluids, etc.
All the hydraulic fluids are classified according to international standards.
Solid contamination is recognised as the main cause of malfunction, failures and early decay in hydraulic systems. It is not possible to eliminate it completely but the contamination can be kept under control with proper devices (filters).
No matter which fluid is used, it must be kept at the contamination level required by the most sensitive component of the system.

HOW TO MEASURE THE CONTAMINATION

The contamination level is measured by counting the number of particles of a certain dimension per unit of volume of the fluid; this number is then classified in Contamination Classes, according to international standards.
The measuring is made with Automatic Particle Counters that can perform live analysis (through sampling connectors mounted in the system for this purpose) or from sampling bottles.
The sampling and the analysis of the fluid must be carried out in compliance with the specific ISO norms.
The most popular standard for Contamination Classes in the hydraulic systems is ISO 4406; the standard NAS 1638 is also quite used.

CONTAMINATION CLASSES ACCORDING TO ISO 4406

Standard ISO 4406 defines three different levels that identify the differentiation of size and distribution of particles.
The code is expressed in three values, that identify in the following order:

- The number of the first scale represents the number of particles equal to or exceeding 4 µm per 1 ml of fluid
- The number of the second scale represents the number of particles equal to or exceeding 6 µm per 1 ml of fluid
- The number of the third scale represents the number of articles equal to or exceeding 14 µm per 1 ml of fluid

For example, the Contamination Class Iso Code 21/12/15 describes a fluid containing:
21 → between 10.000 and 20.000 particles ≥ 4 $\mu m_{(c)}$ per 1 ml
18 → between 1.300 and 2.500 particles ≥ 6 $\mu m_{(c)}$ per 1 ml
15 → between 160 and 320 particles ≥ 14 $\mu m_{(c)}$ per 1 ml

ISO Code	Number of particles per 1 ml	
	more than	up to
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

HYDRAULIC FILTER MEDIA AND RATING

Since over 80% of all system failures are due to contamination, it is extremely important to have high quality hydraulic filters in place. These devices filter out contamination from the fluid, keeping the system running smoothly.
The filter element can be considered as the processor within the filtration computer, that is why extensive knowledge and many years of manufacturing expertise make significant difference in the design and development of filter element performances and reliability.
Depending on the materials and construction, the filters may be able to capture surface and/or depth contamination, with different filtration efficiency.
Hydraulic filter elements normally use one of three different types of media:

- Metal wire mesh: it is a surface filter and it gives a geometrical filtration. Its rating is determined as “Largest diameter of hard spherical particle that will pass through the media”;
- Cellulose (paper impregnated with resin): it is a depth filter media with an irregular structure. It’s classified on average pore dimension.
- Microfiber (inorganic fiber impregnated with resin): it is a depth filter media with regular structure. It’s classified on average pore dimension and it consists of multiple layers. Thanks to the multilayer structure with differential porosity the microfiber media retains even smaller particle sizes than the reference filtration ratio of each filter media.

The last section of this introduction is be dedicated to the filter materials that have been selected and developed in the UFI Innovation Centers worldwide: FormulaUFI.

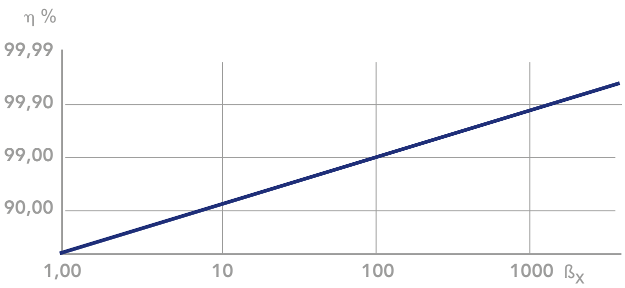
The best and most commonly used rating in industry is the beta rating. The beta rating comes from the Multipass Method for Evaluating Filtration Performance of a Fine Filter Element (ISO 16889).

BETA RATIO

$$\beta_x = (n_{in} = X\ \mu m) : (n_{out} = X\ \mu m)$$

where “n” is the number of particles = x µm
upstream and downstream from the filter.

E.g. if you have 100.000 particles = 10µm upstream
and 1.000 particles downstream:
β_{10} = 100.000 : 1.000 = 100



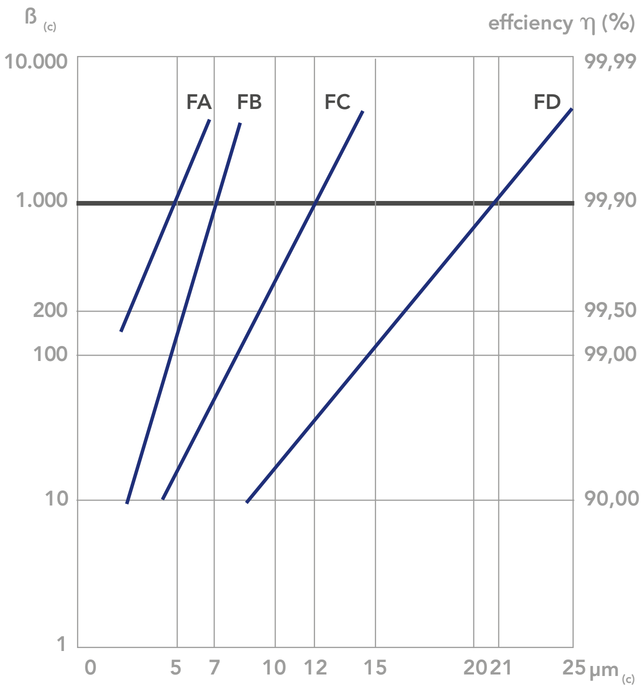
FILTRATION EFFICIENCY η(%):

$$\eta = 100 - (100 : \beta)$$

i.e.
β_x = 2 means = 50,00 %
β_x = 20 means = 95,00 %
β_x = 75 means = 98,67 %
β_x = 100 means = 99,00 %
β_x = 200 means = 99,50 %
β_x = 1.000 means = 99,90 %

FILTRATION IN BRIEF

The actual retention capacity behaviour is described in the graph here below:



REFERENCES FOR THE "BETA" RATIO

The standard ISO 16889 has replaced the former ISO 4572 concerning the Multi-Pass test, stating the Beta value of a filter element, since 1999. The current standard prescribes the test dust ISO MTD instead of the formerly used ACFTD, both in Multi-Pass test rigs as well as the calibration of the automatic particle counters.

According to the ISO 16889 the particles sizes are measured with a different method than according to the ISO 4572.
To avoid any confusion, when microns are measured according to the current specification, they are identified as μm(c).

REAL FLOW RATE THROUGH THE FILTER

In order to properly size the filter, it is essential to calculate the REAL flow rate of the oil passing through it:

- In SUCTION AND PRESSURE FILTERS the flow rate is usually the same as the pump delivery (with the exception of the FPD01 and 12 series, where the flow rate is just the one required by the pilot valve)
- In RETURN FILTERS it is necessary to calculate the maximum possible flow rate, taking into account any potential additional return line, cylinder and accumulator. If such data are unknown, as a good rule a flow rate at least 2 ÷ 2,5 times the pump delivery should be considered.

Filter element life is significantly affected by the pollution level at the machine location and by the maintenance level of the machine. Considering these parameters the actual flow rate should be multiplied by the following "Environmental Factor".

ENVIRONMENTAL FACTOR

System maintenance level	Environment contamination level LOW	MEDIUM	HIGH
• tank with good protection, efficient air breathers • few actuators, with very good protection from contaminant ingression • frequent monitoring of filter conditions	1	1	1,3
• tank with protection, good air breathers • many actuators, with good protection from contaminant ingression • scheduled monitoring of filter conditions	1	1,5	1,7
• tank with poor protection • many actuators, with low protection from contaminant ingressions • random monitoring of filter conditions	1,3	2	2,3
	F. i. system located in climatized room	F. i. system located in industrial building	F. i. system located in hostile environment (foudry, wood workingmachines, mobile machines)

FILTER SIZING AND PRESSURE DROP (ΔP)

The filter sizing is based on the total pressure drop, that depends on the application, the selected filter media, in order to obtain the required oil cleanliness level, and the REAL flow rate.
The pressure drop calculation (“assembly Δp) is performed by adding together the value of the housing ((Δp filter housing) with the value of the filter element (Δp filter element) and should respect the following guidelines:

· **3 kPa** (0,03 bar) max for suction filters
· **35 ÷ 50 kPa** (0,35 ÷ 0,5 bar) max for return filters
· **35 ÷ 50 kPa** (0,35 ÷ 0,5 bar) max for pressure filters < 11 MPa (110 bar)
· **80 ÷120 kPa** (0,80 ÷1,2 bar) max for pressure filters > 11 MPa (110 bar)

Lower initial pressure drop provides better filter efficiency and longer filter element service life.

N.B. The flow rate values given in the tables are referred to mineral oil with kinematic viscosity “V” of 30 cSt and density “ps” = 0,86 Kg/dm^3.
When using oils with different features, the following correction factors must be applied at the Δp_0 values obtained on the curves:
FILTER HOUSING
the pressure drop is directly proportional to the oil density “ps”, so in case you have $ps_1 \neq 0{,}86$ ► $\Delta p_1 = (\Delta p_0 \times ps_1) : 0{,}86$
FILTER ELEMENT
the pressure drop through the filter element varies in function of the kinematic oil viscosity, so in case you have a kinematic viscosity V_1 (cSt) different from cSt:
· for kinematic oil viscosity ≤ 150 cSt ► $\Delta p_1 = \Delta p_0 \times (V_1 : 30)$
· for kinematic oil viscosity > 150 cSt ► $\Delta p_1 = \Delta p_0 \times [V_1 : 30 + \sqrt{(V_1 : 30)}] : 2$
(for more details about kinematic oil viscosity see the diagram on the next page)
Some fluids have **filterability problems** (difficulty in passing through a “multilayer” (glassfiber) filter media).
In such cases a **correction factor** must be considered when sizing the filter: this factor must be verified with the filter manufacturing, specifying all the features of the fluid.
It is a good rule, when sizing the filter, to consider also the max recommended fluid speed:
in suction lines 0,1< v < 1 m/s | in return lines 1,5< v < 4 m/s | in pressure lines 5< v < 10 m/s

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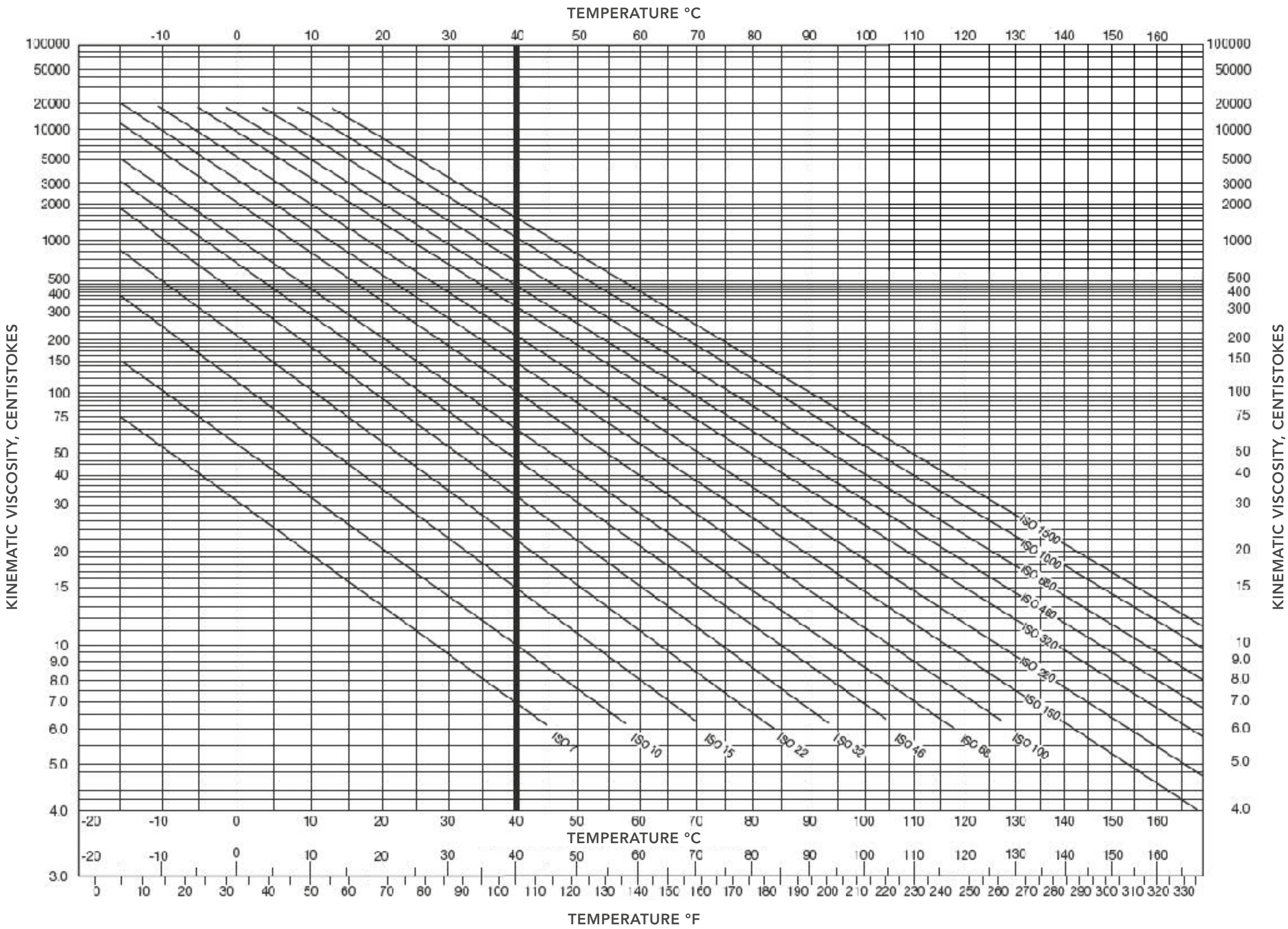
VISCOSITY VS TEMPERATURE



Lines shown refer to oils of ISO preferred grades and V.I. = 100.
Lower V.I. oils will show steeper slopes.
Higher V.I. oils will show flatter slopes.

ISO FLUIDS CLASSIFICATION AND COMPATIBILITY WITH MATERIALS

The below table resume some general indication of fluid classification (ref. ISO 6743) and their compatibility; we recommend to verify the exact features of the fluid with the supplier.

ISO ref.	Type of fluid	Features	Compatibility (10th digit in ordering pn)
HH	Mineral base fluid	No additives	N
HL	Mineral base fluid	Anticorrosion, antioxidation add.	N
HM	Mineral base fluid	Antiwear additives	N
HV	Mineral base fluid	Viscosity improver additives	N
HFA	Fire extinguishing fluid	Oil in water emulsion (water >90%)	G (aluminum and zinc not compatible)
HFB	Fire extinguishing fluid	Water in oil emulsion (water >40%)	G (aluminum and zinc not compatible)
HFC	Fire extinguishing fluid	Water glycol	G (aluminum and zinc not compatible)
HFD	Fire extinguishing fluid	Synthetic fluid (phosforic ester)	F (NBR not compatible)
HTG	Environmentally accepted fluid	Vegetal base fluid	N
HPG	Environmentally accepted fluid	Glycol base synthetic fluid	G (aluminum and zinc not compatible)
HE	Environmentally accepted fluid	Esther base synthetic fluid	F (NBR not compatible)

FILTERS AND FILTER MEDIA

All the hydraulic systems have an initial solid contamination, tending to increase during operation due to component wear, ingression from the external environment, etc. For this reason it is necessary to use filters that retain the contaminant and allow the fluid to reach and maintain the required contamination class.
Depending on their location into the system, the most common filter types are:

- RETURN LINE FILTERS, downstream from all the components, filtering the oil before it returns into the tank. Their function is keeping the required contamination level inside the tank (indirect protection of the components) and must be sized to have a high dirt holding capacity (i.e. a long life). They usually have filter elements by glassfiber (absolute filtration, $\beta x \geq 75$) or by cellulose (nominal filtration, $\beta x \geq 2$).

- PRESSURE FILTERS, on the pressure line, protecting directly one or more components, ensuring they are fed with oil with the proper contamination class. They usually have filter elements made from glassfiber (absolute filtration, $\beta x \geq 75$) or sometimes from cellulose (nominal filtration, $\beta x \geq 2$).

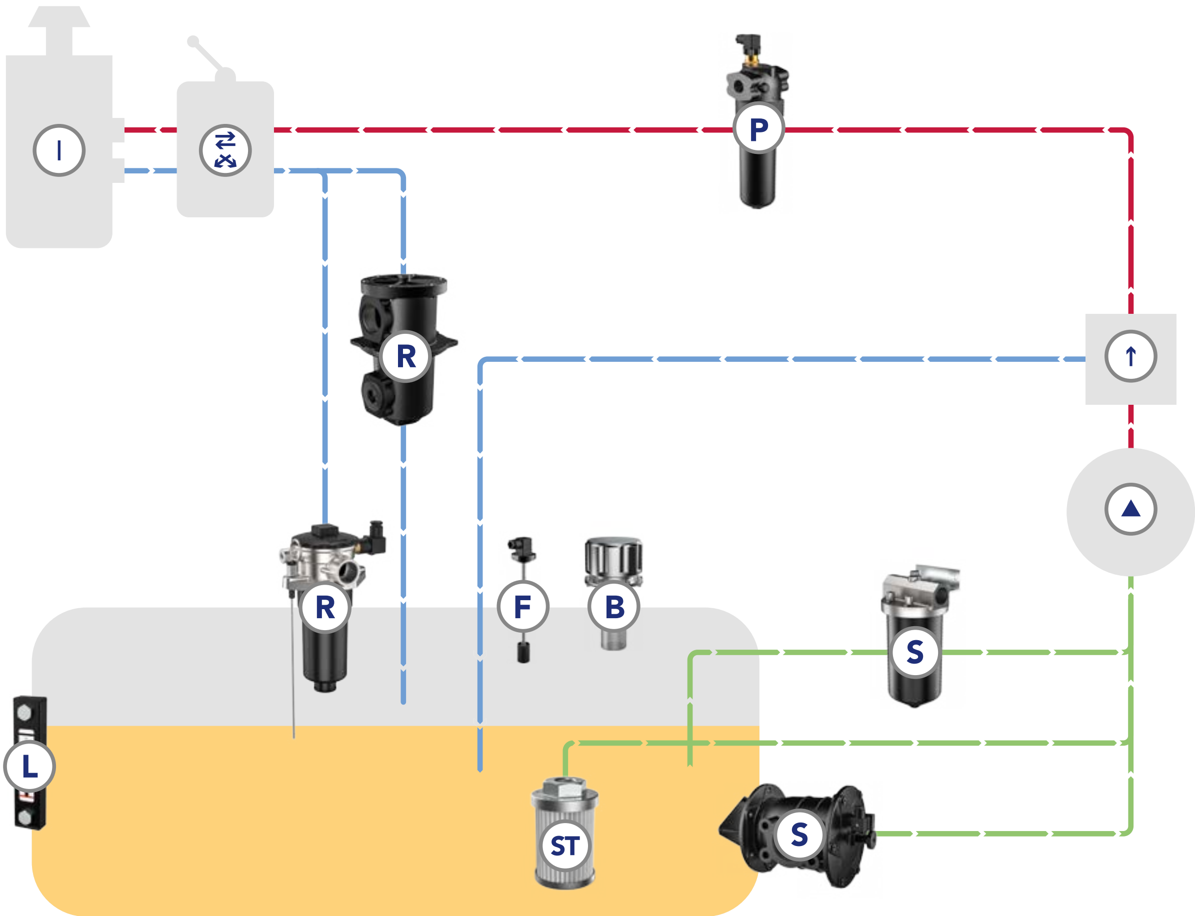
- SUCTION FILTERS, on the suction line, protecting the pump from possible coarse contamination. They usually have filter elements by metal wire mesh (geometric filtration) and must be sized properly, to avoid any possible pump cavitation.

- OFF-LINE FILTERS, generally used when a very low contamination class is required (i.e. very good cleanliness). These filters operate with constant flow rate and pressure, thus resulting in the highest filtration efficiency. Even fresh oil presents a certain contamination, so it is a good rule to make any filling or refilling of the system using an OFF-LINE FILTRATION UNIT.

- AIR FILTERS (breathers), filtering the air drawn into the tank when the oil goes to the actuators, must be used to avoid contaminant ingression from the environment.

FILTRATION IN BRIEF

HYDRAULIC CIRCUIT



KEY

L Level indicator

R Return filter

F Float switch

B Breather

ST Suction strainer

P Pressure filter

S Suction filter

▲ Pump

↑ Pressure regulator

⇄ Directional control valve

I Double acting cylinder

— Suction

— Return

— Pressure

● Oil

FILTER MEDIA AND CONTAMINATION CLASSES

Each hydraulic component manufacturer specifies the contamination class required for the best performance and life of their components.

To achieve the required contamination class, the proper UFI filter media must be chosen according to this table:

Typical application	Aeronautic, test rigs.	Aeronautic, ind. Robotics	Ind. robotics, precision machine tools	High reliability ind. machines, Hydrostatic transmissions	Industrial machines, earth moving machines	Mobile machines	Machines for heavy industry	Machines for agriculture systems not continuos service
Pumps and/or motors	-	Piston, variable > 21 Mpa	Piston, variable < 21 MPa Vane, variable > 14 Mpa	Pist./vane, variable < 14 MPa Pist./vane, flxed > 14 Mpa	Pistons, fixed < 14 Mpa Vane, fixed > 14 Mpa	Vane, fixed gear > 14 Mpa	Vane, fixed gear < 14 Mpa	Vane, fixed gear < 14 Mpa
Valves	Servovalves > 21 Mpa	Servovalves < 21 MPa Proportional > 21 Mpa	Proportional < 21 MPa Cartridge > 14 Mpa	Cartridge < 14 Mpa	Solenoid > 21 Mpa	Solenoid < 21 Mpa	Solenoid > 14 Mpa	Solenoid > 14 Mpa
Contamination class ISO 4406	15/13/10	16/14/11	17/15/12	18/16/13	19/17/14	20/18/15	21/19/16	22/20/17
Recommended UFI filter media	**FA** $\beta_{5(c)} > 1.000$	**FA - FB** $\beta_{5(c)} > 1.000$ $\beta_{7(c)} > 1.000$	**FB** $\beta_{7(c)} > 1.000$	**FB - FC** $\beta_{7(c)} > 1.000$ $\beta_{12(c)} > 1.000$	**FC - FD** $\beta_{12(c)} > 1.000$ $\beta_{21(c)} > 1.000$	**FD** $\beta_{21(c)} > 1.000$	**FD - CC** $\beta_{21(c)} > 1.000$ $\beta_{10} > 2$	**CC** $\beta_{10} > 2$

N.B. NAS 1638 is officially inactive for new designs after May 30, 2001.