Filtration - Why?

Good hydraulic filtration is gaining more and more importance in the use of hydraulic systems.

Reducing contamination in the hydraulic system will reduce the wear of the components and thus extend the service life of the machine. This will prevent production downtime and lower the overall production costs.

Right from the beginning, there is contamination in a new hydraulic system, which reduces the service life of the system and its components such as valves and cylinders without any or with inadequate filtration.

This built-in dirt is created during the manufacturing of the components and mainly consists of coarse particles.

In addition to the contamination that arises during operation of the system, e.g. abrasive wear, dirt particles can also get into the system when it is filled with hydraulic oil.
This is called ingress contamination.

Choosing the right filter contributes significantly to prevent the dangers mentioned above thereby ensuring efficient operation even after many years.

Reduction of Contamination

- Extension of service life
- Extension of maintenance intervals
- Reduction of machine downtime
- Reduction of environmental pollution

▶ **Cost savings for the user**

Origin of Contamination

The main cause of failures and downtimes is dirt in the hydraulic system.

Failure analysis indicate that 80% of the failures are caused by faults in the hydraulic system. 90% of them are caused by impurities in the hydraulic oil.

Sources of External Contamination

- Filling and refilling the hydraulic tank
- Inadequately dimensioned breathers
- Damaged tank seals
- Replacement of hydraulic lines and components (pumps, cylinders)
- Impurities in the air

Types of Internal Contamination

- Contamination on / in the components caused by the manufacturing process (e.g. chips)
- Contamination on the components caused by the installation of the components

Sources of Internal Contamination

- Disintegration of particles from high pressure changes and tension on the surface of hydraulic components (e.g. cavitation)
- Material erosion that occurs at places in the hydraulic units due to the impact of pressurised liquid at high speeds (erosion wear)

Contamination

Particle Sizes (Selection)

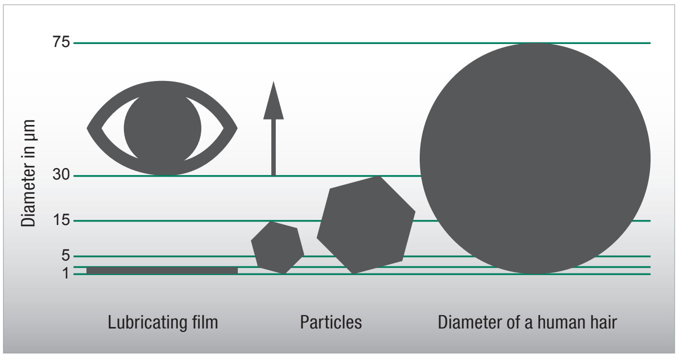
- 100 µm table salt, fine sand
- 75 µm diameter of a human hair
- 60 µm flower pollen
- 50 µm fog
- **30 µm (from approx.) resolution of the human eye**
- 15 µm fine particles
- 7 µm red blood cells
- 2 µm bacteria
- 1 µm layer of lubricating film (for comparison)

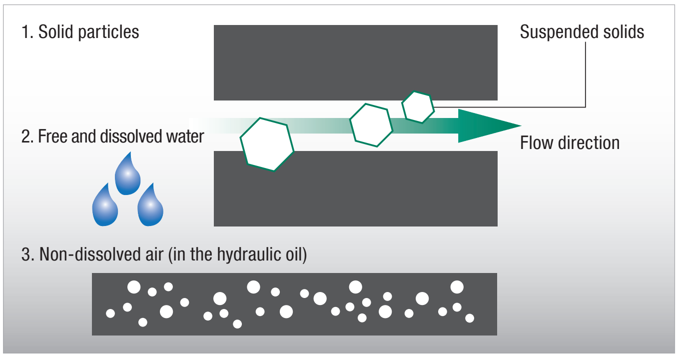
Type of Contamination

The most frequent ones are:

- Solid particles
- Free and dissolved water
- Non-dissolved air

A majority of the contamination can be removed with filtration.

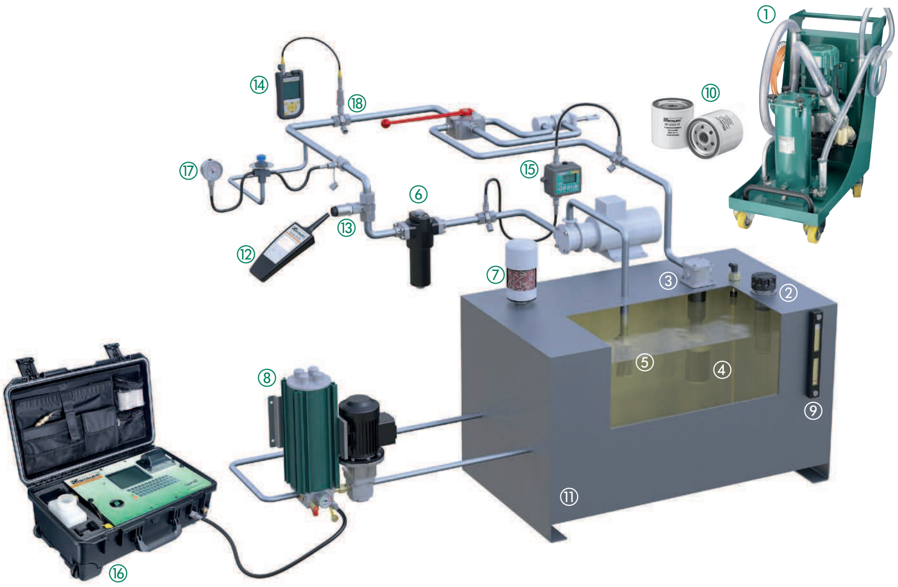


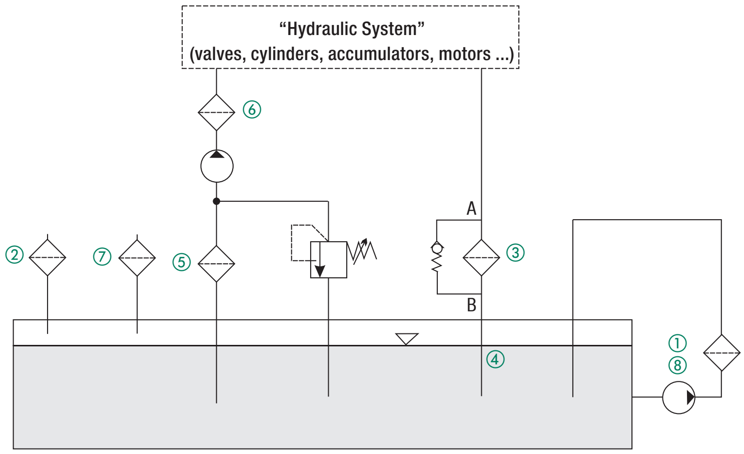


STAUFF Laser Particle Counter
LasPaC-II and Bottle Sampler

Selection of Components within the Hydraulic Circuit

①	STAUFF Mobile Filter System	**SMFS-U**
②	STAUFF Plastic Filler Breather	**SPB**
③	STAUFF Return-Line Filter	**RF**
④	STAUFF Diffusor	**SRV**
⑤	STAUFF Suction Strainer	**SUS**
⑥	STAUFF Pressure Filter	**SF**
⑦	STAUFF Desiccant Air Breather	**SDB**
⑧	STAUFF Offline Filter	**OLS**
⑨	STAUFF Level Gauge	**SNA**
⑩	STAUFF Spin-On Filter	**SSF**
⑪	Oil tank	
⑫	STAUFF Reader	**PT-RF**
⑬	STAUFF Pressure Transmitter	**PT-RF**
⑭	STAUFF Hydraulic Tester	**PPC**
⑮	STAUFF Particle Monitor	**LPM-II**
⑯	STAUFF Laser Particle Counter	**LasPac-II**
⑰	STAUFF Pressure Gauge	**SPG**
⑱	STAUFF Test Coupling	**SMK / SKK**





STAUFF Filter Components

Pressure Filters Series SF / SF-TM / SFZ / SFA / SMPF (see page 34 - 35)

Return-Line Filters Series RF / RFA / RFB / RFS / RTF (see page 66 - 125)

Diffusers / Suction Strainers / Filler Breathers / Desiccant Air Breathers
(see Catalogue No. 10 - Hydraulic Accessories)

Offline and Bypass Filters / Mobile Filter Units
(see page 178 - 209)

Spin-On Filters (see page 148 - 177)

Pressure Filters ⑥ are placed behind the pump and clean the hydraulic oil before it flows through down-stream components like valves, cylinders and so on. The main reason for pressure filtration is the protection of downstream, sensitive components.

Eroded particles from the pump are immediately filtered out of the hydraulic oil. Besides working as a protection filter, Pressure Filters also help to maintain the required purity class.

Because it is placed right behind the pump, a Pressure Filter has to withstand the maximum system pressure. The filter element in the Pressure Filter also has to withstand the loads and is more intricately constructed, for example as a Return-Line Filters element.

Return-Line Filters ③ are installed in the Return-Line, on top of or within the oil tank. They filter the hydraulic oil before it flows back into the reservoir. This ensures that contamination arising in the components does not get into the tank. Return-Line Filters maintain the targeted purity class like Pressure Filters. However, because of their arrangement, they do not fulfil the additional function of a protection filter. In contrast to a Pressure Filter, it only has to withstand low pressure levels.

Diffusers ④ are used in combination with Return-Line Filters and ensure that the returning oil flow is settled before it reaches the oil tank thereby preventing foaming and re-suspension of deposited dirt.

The job of **Suction Strainers** ⑤ is mainly to provide functional protection of the downstream pumps in the circulation. Suction Strainers always have to be provided if the risk of pump damage from coarse impurities is particularly high. This risk exists if impurities are collected in the tank and if they can't be filtered out afterwards. Suction Strainers are coarse filter elements with a micron rating that is usually bigger than 100 µm.

Filler Breathers ② are mounted on the oil tank and prevent the entry of dirt from the surroundings during tank breathing. They should be chosen with a filter unit that is similar to the working filter (Pressure Filter, Return-Line Filter).

The replacement cycles of filter inserts is highly dependent on the surrounding conditions of the hydraulic system.

Another variant of the breather is the **Desiccant Air Breather** ⑦ . The additional function of this filter is dehumidification of the inflowing air with a special silicate gel.

Offline / Bypass Filters ⑧ / ① are not part of the main hydraulic system. They are supplementary to achieve the best possible filtration results. Because of the high efficiency of the Offline / Bypass Filters, purity levels are reached that cannot be achieved with conventional main filter systems.

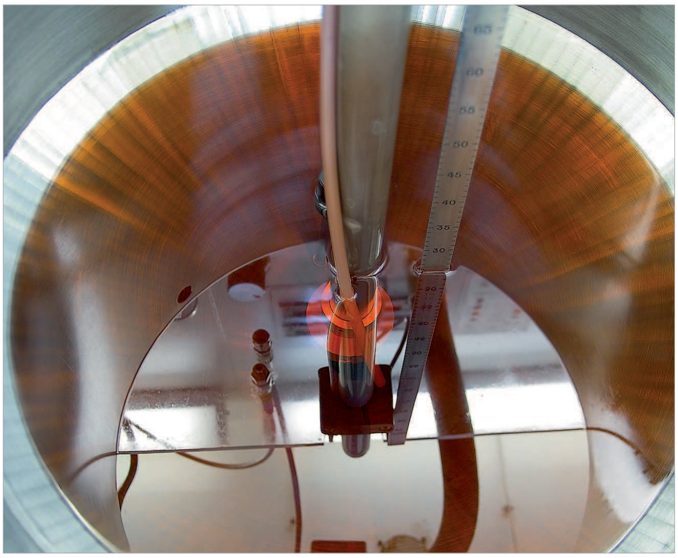
Offline Filters work with an integrated motor / pump unit that draws in the fluid from the system, filters it and then feeds it back into the tank. Because the offline filter is independent from the hydraulic main circuit, i.e. it can still be operated if the hydraulic system is switched off, it is used in practice for continuous cleaning of the tank.

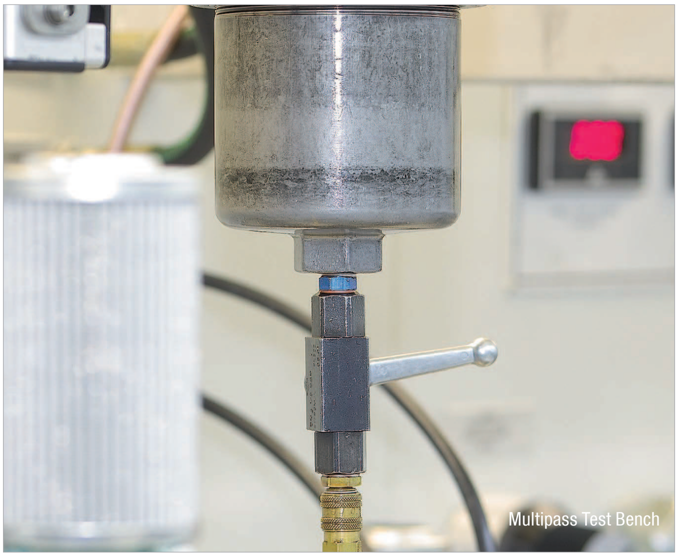
Bypass Filters on the other hand use the existing system pressure to draw a small volumetric flow out of the hydraulic system for filtration. They are only active while the unit is in operation.

Another mobile variant of the bypass filter is the **Mobile Filter System** ①.

STAUFF provides a complete range of **Spin-On Filters** ⑩ which can be used either as Suction Filters or as Return-Line filters for low pressure applications.

A





Multipass Test Bench

Test Standards and Oil Purity

Definition of the Required Micron Rating

Essentially, the components found in the hydraulic system determine the micron rating of the filtration system.

To guarantee a reliable mode of operation over the years, it is mandatory to maintain the optimum oil purity class for specific components.

The most sensitive component determines the choice of filter material and micron rating.

To determine the oil purity according to ISO 4406 (1999), a laser particle counter is used to count particles that are >4 µm $_{(c)}$, >6 µm $_{(c)}$ and >14 µm $_{(c)}$ in 100 ml of hydraulic oil. The number of particles is then assigned with a classification number (e.g. 14/11/8) that then corresponds to the ISO purity class. Please note here that the number of particles doubles for the next higher class. The cleanliness level that has to be achieved is an important criterion for choosing the right filtration system.

STAUFF Filter Elements are subject to the following Test Methods

- ISO 2941 Collapse and burst resistance
- ISO 2942 Verification of fabrication integrity (bubble point test)
- ISO 2943 Compatibility with hydraulic media
- ISO 3723 End load test
- ISO 3724 Flow fatigue characteristics
- ISO 3968 Flow characteristics
- ISO 16889 Filtration performance test (multi-pass method)

Number of particles in 100 ml fluid		Classification numbers ISO 4406 (1999)		
More than	Less than	> 4 µm$_{(c)}$	> 6 µm$_{(c)}$	> 14 µm$_{(c)}$
16000000	32000000	25	25	25
8000000	16000000	24	24	24
4000000	8000000	23	23	23
2000000	4000000	22	22	22
1000000	2000000	21	21	21
500000	1000000	20	20	20
250000	500000	19	19	19
130000	250000	18	18	18
64000	130000	17	17	17
32000	64000	16	16	16
16000	32000	15	15	15
8000	16000	**14**	14	14
4000	8000	13	13	13
2000	4000	12	12	12
1000	2000	11	**11**	11
500	1000	10	10	10
250	500	9	9	9
130	250	8	8	**8**
64	130	7	7	7
32	64	6	6	6
16	32	5	5	5

STAUFF Laser Particle Counter
LasPaC-II, LPM-II
and Bottle Sampler

Short & Curt: Filter Rating

(For exact recommendation see SCCP - STAUFF Contamination Control Program see on page 15)

Type	Component	ISO 4406 Code	Recommended Filter Rating
Pump	Piston Pump (Slow Speed, Inline)	22/20/16	20 µm
	Gear Pump	19/17/15	20 µm
	Vane Pump	18/16/14	5 µm
	Piston Pump (High Speed, Variable)	17/15/13	5 µm
Motor	Gear Motor	20/18/15	20 µm
	Vane Motor	19/17/14	10 µm
	Radial Piston Motor	19/17/13	10 µm
	Axial Piston Motor	18/16/13	5 µm
Valve	Directional Valves (Solenoid)	20/18/15	20 µm
	Check Valves	20/18/15	20 µm
	Logic Valves	20/18/15	20 µm
	Cartridge Valves	20/18/15	20 µm
	Pressure Control Valves (Modulating)	19/17/14	10 µm
	Flow Control Valves	19/17/14	10 µm
	Standard Hydraulic <100 bar / <1450 PSI	19/17/14	10 µm
	Proportional Valves	18/16/13	5 µm
	Servo Valves <210 bar / <3045 PSI	16/14/11	3 µm
	Servo Valves >210 bar / >3045 PSI	15/13/10	3 µm
Actuator	Cylinder	20/18/15	20 µm

ß-Value and Separations Efficiency

To select filtration that meet the requirements, performance characteristics like the filter fineness, the filtration efficiency, the dirt-hold capacity and the pressure loss has to be observed.

The ß-value as per ISO 16889 is the relevant characteristic value for the filtration efficiency. The ß-value is the ratio of particles before ($N_{up\ x}$) and after ($N_{down\ x}$) the filter related to a specific particle size x.

$$ß_x = \frac{N_{up\ x}}{N_{down\ x}}$$

$ß_{10} > 200$ means that of 1000 particles that are 10 µm in size, only five particles can pass through the filter. 995 particles will be trapped by the filter element.

Popular filters with inorganic glass fibre medium have to achieve a ß-value of at least 200 in order to meet the demands placed on hydraulic filtration today.

The filtration efficiency, also called the retention rate, is directly related to the ß-value and is calculated as follows:

$$E = \frac{(ß_x - 1)}{ß_x}$$

$ß_{10} > 200$ corresponds to filtration efficiency of 99,5%.

Comparison of the ß-Value and Efficiency E (each related to a defined Particle Size)

ß-value	Filtration Efficiency E
1	0,00 %
2	50,00 %
10	90,00 %
25	96,00 %
50	98,00 %
75	98,67 %
100	99,00 %
200	99,50 %
1000	99,90 %
9999	99,99 %

The **dirt-hold capacity** (DHC) shows how much solid dirt a filter element can hold before it has to be replaced. The dirt-hold capacity is therefore the most important parameter in the filter service life.

The **differential pressure** (Δp) is another important criterion for the configuration of the filter. Ensure that the size of the filter element is chosen according to the calculation guideline by STAUFF.

To guarantee optimum filtration, the ß-value, the dirt-hold capacity (DHC) and the differential pressure (Δp) must be carefully matched.

Filtration Terminology

ß-value

The ß-value as per ISO 16889 is the relevant characteristic value for filtration efficiency. The ß-value is the ratio of particles before ($N_{up\ x}$) and after ($N_{down\ x}$) the filter related to a specific particle size x.

$$ß_x = \frac{N_{up\ x}}{N_{down\ x}}$$ (see page 19)

Cavitation Damage

Cavitation is defined to be the cavity formation in liquids. Cavitation occurs if the local static pressure of a liquid drops below a critical value. This critical value usually corresponds to the vapour pressure of the liquid. Critical effects of cavitation are:

- Cavitation wear
- Undissolved gas in the hydraulic system
- Loud high-frequency noises
- Local high temperatures in the liquid
- Changes to the resistance characteristics of the hydraulic resistance

Cleanliness Level

The cleanliness level of a hydraulic fluid is defined by the number of solid particles per ml of fluid. The number of particles is usually measured with an automatic particle counter. The cleanliness level is determined by a class code created by counting the number of particles of different sizes.

Particle counting as well as the coding of the cleanliness class for hydraulic oils are described in the ISO 4406 (1999) standard. Beside the ISO 4406 (1999), NAS 1638 (1964) and SAE AS4059 Rev. D (2001) are also still common.

Clogging Indicator

The clogging indicator signalises a specific pressure level where the soiled filter element should be replaced. They work with differential pressure (Δp) or back pressure. Clogging indicators are available in visual, electrical and visual / electrical versions. While it is the responsibility of the installation or maintenance personnel to check the degree of clogging of the filter element with visual clogging indicators, a signal contact (switch) can be connected to the machine controller with an electrical or visual / electrical clogging indicator.

Collapse Pressure

The permissible collapse pressure according to ISO 2941 is understood to be the pressure difference that a filter element can withstand with the stipulated direction of flow. Exceeding the collapse pressure results in the destruction of the filter element.

Depth Filter

Impurities penetrate into the filter fabric and are retained by the structure of the filter fabric. Mainly cellulose and inorganic glass fibre media are used in hydraulic filters. For special applications, Plastic Media (high-strength) and Stainless Fibre media are also used. The design of the depth filter combines the highest micron rating with a high dirt retention capacity. Due to the fleece-like structure of depth filters, particles are not only separated on the surface of the filter material, but they can penetrate into the filter material, which leads to a considerable increase of the effective filter area. In contrast to sieves, there are no holes in fleece, rather they practically consist of labyrinths in which the particles are trapped. Hence, there is no sharply defined screening, rather a wide range of particles are trapped.

Differential Pressure

The differential pressure (Δp) is defined as the pressure difference between the filter inlet and the filter outlet, or alternatively in front of and behind the filter element.

Exceeding the maximum permissible pressure differential leads to the destruction of the filter element.

An integrated bypass valve in the filter prevents destruction of the filter element by opening if the differential pressure (Δp) is too high. Then the oil is passed unfiltered into the hydraulic circuit. For applications in which no unfiltered oil is allowed to pass into the hydraulic circuit, there is the possibility of using filters without bypass valves with filter elements that can withstand a high differential pressure (Δp). The filter elements must be designed such that they can withstand the maximum expected differential pressure (Δp).

Dirt-Hold Capacity (DHC)

The dirt-hold capacity (DHC) shows how much solid dirt a filter element can hold. It is measured in the multipass test according to ISO 16889.

Filter

A filter (hydraulic filter) has the job of keeping solids out of a liquid (oil). A filter is usually made of an filter housing and a filter element.

Filter Area

The filter area is the size of the theoretically spread-out filter element. The larger the filter area, the lower the flow resistance of the filter element. Simultaneously, the dirt-hold capacity (DHC) increases. The following applies in general: the larger the filter area, the longer the service life of the element. Basically the filter area can be enlarged by the number of pleats.

Filter Cake

A filter cake is made up of the particles trapped on the surface of a filter medium.

Filter Design

Essentially depends on the following factors: specific flow rate, cleanliness level, amount of contamination, the maximum pressure setting and the required filter service life.

Filter Element

The filter element is located in the filter housing and performs the actual filtering task.

Filtration Efficiency

Filtration efficiency E is a measure of the effectiveness of a filter element for separating solid particles. It is given in percent.

Filter Housing

Depending on the application, the filter housing is built into the pressure or Return-Line and must be designed for the specific operating or system pressure and the flow rate. The filter element is located in the filter housing. Depending on the application, the filter housing may be equipped with a bypass valve, a reversing valve, a clogging indicator and other options.

Filter Material

The choice of the right filter material is dependent on different criteria. Amongst others, this includes the type of application, the filter function, degree of contamination or alternatively the required dirt-hold capacity (DHC) as well as requirements of chemical or physical resistance. The following list gives you an overview of how these filter materials differ with regard to specific properties:

Inorganic Glass Fibre

Inorganic Glass Fibre media are among the most important materials in modern filtration. During production, selected fibres (1 mm ... 5 mm long and with a diameter of 3 µm ... 10 µm) are processed into a specific mix. The manufacturing process is very similar to paper production. The fibres are bound with a resin and impregnated. The benefit compared to cellulose paper is a fibre structure that is considerably more homogenous and consequently has larger open pored surfaces. As a result, lower flow resistance is achieved.

- Based on Glass Fibres with acrylic or epoxy resin binding
- High retention and dirt-hold capacity (DHC)
- Excellent separation efficiency of the finest particles due to the three-dimensional labyrinth structure with deepth filtration
- Outstanding price / performance ratio

Filter Material (Continuation)

Polyester
- 100% Polyester Fibres with thermal bonding
- High pressure differential resistance
- Good chemical resistance
- High separation efficiency of the finest particles
- Tear-proof structure

Cellulose
- Filter material made of Cellulose Fibres with special impregnation
- Variants with the lowest price with good dirt retention capacity
- Not suitable for water based media

Stainless Fibre
- Sintered Stainless Fibres with three-dimensional labyrinth structure for depth filtration
- Low flow resistance with high dirt-hold capacity
- Excellent chemical and thermal resistance

Stainless Mesh
Filter elements with a Metal Wire Mesh are often used as a conditionally reusable solution in protection filters, Suction-Line Filters or Return-Line Filters. Depending on the requirements (micron rating, pressure, dynamics) different types of mesh are used like twill, linen, or also Dutch weave.

- Wire mesh fabric made of material 1.4301 or 1.4305 for surface filtration (other material on request)
- Low flow resistance due to large-pored screening surface
- Excellent chemical and thermal resistance
- Cleanable under special conditions

Flow Rate
This is the amount of fluid that flows past a specific cross-section per unit time. It is given in litres per minute (l/min) or gallons per minute (US GPM).

Hydraulic Fluid
A pressure liquid is defined to be a fluid used in hydraulic and lubrication systems. According to ISO 6743, the fluids are divided into mineral oil based, flame resistant and biodegredable liquids.

Micron Rating
Regarding micron rating, we must differentiate between the filter materials that are used. To define the micron rating for Inorganic Glass Fibre filter elements, the ß-value as per ISO 16889 is commonly used.

Absolute and Nominal micron rating
Micron rating is the size of particles which are filtered out by filters at a certain efficiency. When this efficiency is at least 99.5%, we speak about absolute micron rating/filtration.

Nominal micron rating is just a commercial trick for all efficiencies lower than 99.5%, meaning that for the same micron rating (for ex. 5 µm) in the case of nominal rating, not all particles will be captured in the filter as in the case of absolute micron rating.

Multipass Test
The Multipass Test evaluates the performance of a filter element. Standardised in ISO 16889-2008, this test allows comparable and repeatable results of the elements performance. If a normal filter element life is between a few weeks up to several months, this test reduces this life down to 90 minutes. The element is subjected to a fluid that a large amount of a special test dust ISO MTD contains. Results are given for the ß-ratio, dirt-hold capacity (DHC) and differential pressure. It is used for designing hydraulic circuits, developing new filter materials and comparison of different filter elements.

See also page 18 and page 19 to get more information about the outcome data.
In former time this test was also known as the Multipass Test ISO 4572.

Nominal Flow Rate
The nominal flow rate describes the flow rate or the volumetric flow rate for which the respective filter has been designed. It is usually given in litres per minute (l/min) or US Gallons per minute (US GPM) and is an important parameter in the filter design.

Nominal Pressure
Pressure for which the filter is designed and which it can be identified with.

Operating Pressure / System Pressure
Maximum pressure with which the filter may be used.

Surface Filter
Impurities are separated on the surface of the filter element. Surface filters are designed to have uniform pores (gaps), therefore they can almost completely retain specific particle sizes. Surface filters are made of Metal Wire Mesh or Cellulose materials.

Other surface filters are metal-edge filters.

Valve

Bypass Valve
A bypass valve is a valve that is integrated in a filter or filter element and allows the oil to bypass the contaminated filter element if a defined pressure differential is exceeded. Bypass valves are used to protect the filter element.

Non-Return Valve
It prevents the continuation line from draining while the filter element is changed.

Reverse Flow Valve
It is used to bypass the filter element for reversible oil flow so that the fluid does not pass through the filter element in the reverse direction.

Multi-Function Valve
A combination of bypass, reverse flow and non-return valve.

Viscosity
The viscosity of a fluid describes the flow behavior of a liquid. There are the kinematic viscosity υ with the unit “m²/s” and the dynamic viscosity η with the unit “Ns/m²”. In the field of filtration, in the design of filters the kinematic viscosity is required for calculating. The kinematic viscosity υ can also be calculated with the dynamic viscosity η and density ρ:

$$\upsilon = \frac{\eta}{\rho}$$

The kinematic viscosity unit is “mm²/s”, before it was called centistokes or Stokes (1 cSt = 1 mm²/s = 10^{-6}m²/s). The unit of dynamic viscosity is “Ns/m², it was previously reported in Poise (10 P = 1 Ns/m² = 1 Pa s).

Choice of Filters

Choice of a Suitable Micron Rating

Generally, the type of components incorporated in the hydraulic system will determine the micron rating required. It has been clearly demonstrated that system components will operate reliably for years if a specific minimum oil cleanliness grade is maintained. Frequently the choice will be determined by the most sensitive component in the system.

a) Operating Filter

To get a rough, first rating of what filter is needed to assure a certain oil cleanness grade please have a look at page 19.

Apart from the specific flow rate (l/min per cm² of filter area), other factors such as operating environment and condition of seals and breathers can have an effect on the cleanliness grade which can actually be achieved.

b) Protective Filter

Occasionally, protective filters are fitted downstream of major components, e.g. the pump, to collect the debris in case of a catastrophic failure. This avoids total stripping and flushing of the system. For economic reasons, protective filters are normally one grade coarser than the operating filters since they do not significantly contribute to the cleaning of the system and this extends filter service intervals.

Choice of the Optimum Filter

In selecting the filter, the following information must be considered:

- Maximum flow volume (Q_{max}) through the filter including surge flows
- Kinematic viscosity (υ) of the fluid in mm^2/s (cSt) at cold start temperature and operating temperature
- Density ρ of the fluid
- Micron rating (µm): see table on page 19
- Filter material

The aim is to choose a filter whose total differential pressure (Δp) is not higher than Δp_{max} = 1,0 bar (for Pressure Filters) or Δp_{max} = 0,5 bar (for Return-Line filters), in a clean state at the normal operating temperature. These values have been proven in practice to give the optimum service life for the element.

The nominal flow volume of the filter is the obvious reference value for pre-selection and this should be larger than the flow to be filtered.

$$Q_{nom} > Q_{max}$$

Calculations based on the filter data will verify whether the pre-selected filter meets the requirements, at operating temperatures:

$$\Delta p_{max} \leq 1{,}0 \text{ bar (for Pressure Filter)}$$
$$\Delta p_{max} \leq 0{,}5 \text{ bar (for Return-Line Filter)}$$

The total differential pressure of the assembly Δp_{Assy} is calculated by adding the differential pressure of the housing Δp_{Hous} and that of the element Δp_{Elem}. Both the kinematic viscosity and density of the operating medium should be considered for the selection, as the flow curves on the pages following have been determined with a kinematic viscosity of υ = 30 cSt and a density of ρ = 0,86 kg/dm³. The values of the pressure drops for the Δp_{Hous} and the Δp_{Elem} can be read from the flow curves on the pages following. The values for the kinematic viscosity in cSt and the density in kg/dm³ should be inserted into the following formula:

$$\Delta p_{Assy} = \frac{\rho}{0{,}86} \cdot \Delta p_{Hous} + \frac{\rho}{0{,}86} \cdot \frac{\upsilon}{30} \cdot \Delta p_{Elem}$$

The filter size is suitable if the $\Delta p_{Assy} < \Delta p_{max}$.
If the calculated Δp_{Assy} is higher than Δp_{max} select the next larger filter size and re-calculate until a satisfactory solution is found.

The following two examples explain and help to understand the procedure of calculating a filter.

Examples of Calculation

Example 1: Selection Pressure Filter

System Information: A Pressure Filter with an Inorganic Glass Fibre element is required immediately after the pump. The system has standard components and is operating at pressures up to 200 bar. The filter shall be fitted with a bypass valve and a visual clogging indicator.

For better understanding only the calculation at the upper temperature is carried out.

Data given:	Q_{max}:	100 l/min
	Oil type:	ISO 68
	Temperature max.:	+50°C
	Viscosity $\upsilon_{operating}$:	44 mm²/s
	Density ρ:	0,882 kg/dm³
	Micron rating:	10 µm (see table on page 19)

First Step

Pre-selection of the size: SF-045, $Q_{nominal}$ = 160 l/min > Q_{max}

Pressure drop values (at viscosity of 30 mm²/s) from the flow characteristics:

Δp_{Hous} = 0,15 bar (SF-045 ..., see page 40)
Δp_{Elem} = 0,77 bar (SE-045-G -10- B/4, see page 40)

Determination of the correction factor:

$$\Delta p_{Assy} = \frac{0{,}882}{0{,}86} \cdot 0{,}15 \text{ bar} + \frac{0{,}882}{0{,}86} \cdot \frac{44}{30} \cdot 0{,}77 \text{ bar}$$

$$\Delta p_{Assy} = 1{,}31 \text{ bar} \geq \Delta p_{max} = 1{,}0 \text{ bar}$$

Since the actual pressure drop is larger than the allowed pressure drop, a larger filter has to be chosen.

Second Step

Selection of the next larger filter size: SF-070, $Q_{nominal}$ = 240 l/min > Q_{max}

Δp_{Hous} = 0,15 bar (SF-070 ..., see page 40)
Δp_{Elem} = 0,45 bar (SE-070-G-10-B/4, see page 40)

$$\Delta p_{Assy} = \frac{0{,}882}{0{,}86} \cdot 0{,}15 \text{ bar} + \frac{0{,}882}{0{,}86} \cdot \frac{44}{30} \cdot 0{,}45 \text{ bar}$$

$$\Delta p_{Assy} = 0{,}83 \text{ bar} \leq \Delta p_{max} = 1{,}0 \text{ bar}$$

In a clean state, this filter fulfills the requirements and is suitable for the application. The correct filter designation would be **SF-070-G-10-B-T-G20-B-V**.

Example 2: Selection Return-Line Filter

System Information: A Return-Line filter with a Cellulose element with a micron rating of 10 µm is required to clean the oil. No clogging indicator is required.

Please note: If the system incorporates either accumulators or cylinders, the return flow can dramatically exceed pump flow and the maximum surge flow should be the flow used to calculate the pressure drop through the filter.

Data given:	Q_{max}:	100 l/min
	Oil type:	ISO 68
	Temperature max.:	+60°C
	Viscosity $\upsilon_{operating}$:	29 mm²/s
	Density ρ:	0,882 kg/dm³
	Micron rating:	10 µm (see table on page 19)

First Step

Pre-selection of the size: RF-030, $Q_{nominal}$ = 110 l/min > Q_{max}

Pressure drop values (at viscosity of 30 mm²/s) from the flow characteristics:

Δp_{Hous} = 0,30 bar (RF-030 ..., see page 72)
Δp_{Elem} = 0,067 bar (RE-030-N-10-B, see page 72)

Determination of the correction factor (see page 22):

$$\Delta p_{Assy} = \frac{0{,}882}{0{,}86} \cdot 0{,}30 \text{ bar} + \frac{0{,}882}{0{,}86} \cdot \frac{29}{30} \cdot 0{,}067 \text{ bar}$$

Δp_{Assy} = 0,37 bar ≤ Δp_{max} = 0,5 bar

In a clean state, this filter fulfills the requirements and is suitable for the application. No further calculation is necessary. The correct filter designation would be **RF-030-N-10-B-G16**.