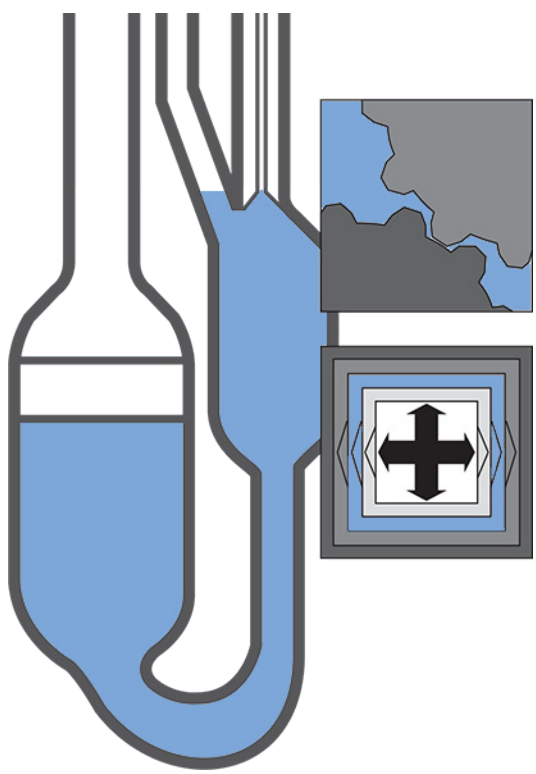
ENGINEERING TOMORROW

Technical Information

Hydraulic Fluids and Lubricants
Guidelines for Cleanliness



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Initial questions and answers

Purpose

This leaflet is intended to assist the designer of an installation, a set or a hydrostatic drive to ensure that the requirement for a specific minimum cleanliness of the hydraulic fluid is met by means of design measures such as the selection of an optimal filter, or preferably of an economically efficient filtration concept. This includes start-up, operation and topping up of hydraulic fluid.

Why is filtration necessary?

In hydrostatic systems a series of sliding surfaces act as hydrostatic-hydrodynamic bearings with gap heights in the range of 10 µm. That is why dirt is the greatest enemy of hydraulic systems, since depending on its nature and composition it generates wear and thus shortens service lives.

This is true for all fields of mechanical engineering and it cannot be repeated often enough. At the present time it is not possible to predict the length of the service life of a hydrostatic unit as a function of the cleanliness of the hydraulic fluid. The fact that these constraints are not known for roller bearings either, even though very many parameters have been researched for these parts in particular, shows just how complicated these wear mechanisms are.

Although more effort is currently being concentrated on trying to measure dirt sensitivity of hydrostatic units in short-term contamination tests, such experiments are unsuccessful because contamination sensitivity cannot be measured like pressures or speeds. The leading manufacturers of hydrostatic equipment have therefore decided to give priority to investigating the fundamentals of wear caused by contamination in hydrostatic units within the framework of a joint research project.

It is uncertain to what extent service life prognoses will be possible at the end of the research project, if at all. It can, however, be stated that **the cleaner a system, the higher its service life expectancy.**

A satisfactory service life is achieved if the cleanliness level as required below is maintained.

Where does the dirt come from?

We distinguish between two essential sources of dirt:

- contamination occurring during assembly – **assembly dirt**
- contamination occurring during operation – **operating dirt**

Assembly dirt

Different kinds of dirt occur during the various production operations: chips, moulding sand, core residues, cleaning-rag lint, welding beads, scale etc. Products supplied by Danfoss are therefore cleaned in modern cleaning installations after completion of machining operations on the individual parts. Careful attention is also paid to cleanliness when these clean individual parts are assembled to form highgrade hydrostatic units. However, since dirt occurs during the final assembly in a vehicle, of a set etc., especially during the piping work, it is advisable to flush the whole system prior to commissioning.

The basic contamination of the "clean" hydraulic fluid supplied must also be added to the assembly dirt. As investigations have shown, new hydraulic fluid can contain basic dirt levels in excess of the cleanliness level admissible for optimum operation, *see Fluid cleanliness requirements on page 10*. That is why a system should always be filled up via a filter assembly. Particles of the same order of magnitude as the gap widths are to be considered as especially critical.

Operating dirt

Fine dirt from the surrounding environment is drawn into the hydraulic system during operation via piston rods or other moving seals. Abrasive particles from the components are also pumped through the system with the fluid. A frequently underestimated source of contamination is from unsuitable venting facilities of fluid tanks. Fluctuations in volume cause fine dust to be drawn into the tanks, from where it causes abrasion of the sliding combinations in the system.

Initial questions and answers

How can the required cleanliness level be achieved?

A filtration system must be designed in such a way that it is able to retain the new dirt entering the overall system in the filter in order to maintain the required cleanliness level throughout the whole operating life.

An example description:

If a filter is used in the suction line or the charge circuit, the charge pump size selected - in our example 17 cm^3 – determines the volume flow available for filtering as a function of the speed. The following theoretical calculation serves to illustrate this (*see Schematic of Series 90 variable pump with suction filter on page 6*).

Assuming that the pump runs at a nominal speed of 1500 min^{-1}, then at an assumed volumetric efficiency of 90 %, a charge pump volume flow of approx. 23 l/min results.

A contamination level of 230 particles larger than 10 µm/ml has developed in the oil tank and a filter with $\beta_{35} = 75$, $\beta_{10} = 2$ (= 50 % filtration efficiency) is fitted in the suction line. The contamination is also distributed uniformly in the fluid. Approximately 5.3 x 10^6 particles larger than 10 µm per minute are now drawn from the tank with the charge pump flow. The filter element holds back 50 % of the particles larger than 10 µm, so that 2.65 x 10^6 particles larger than 10 µm reach the charge pump each minute.

If 2.65 x 10^6 particles larger than 10 µm are also passed to the system per minute (via ventilation filters, piston rods or abrasion), there is no change in the cleanliness level. If fewer than 2.65 x 10^6 particles larger than 10 µm are passed to the system, a lower i. e. a better cleanliness level is achieved. However if more than 2.65 x 10^6 particles larger than 10 µm are passed to the system, a higher i. e. a worse cleanliness level is achieved.

As mentioned at the beginning, this calculation is very close to conditions encountered in practice, but these will never be so exact because particles will settle at the bottom of the tank in areas with a low flow velocity. Nor are the particles so uniformly distributed when they pass through the filter. This example is merely intended to illustrate the principle and it can be established that:

The cleanliness level is improved if:

- the filter fineness is improved (higher β-value for a certain particle size, i. e. $\beta_{10} = 2$ becomes $\beta_{10} = 2.5$)
- the volume flow* via the filter is increased

The cleanliness level deteriorates if:

- the filter fineness deteriorates (lower β-value for a certain particle size, i. e. $\beta_{10} = 2$ becomes $\beta_{10} = 1.8$)
- the volume flow via the filter is reduced. (Note the change of the β-value shown in the diagram *Retention rate as a function of the differential pressure*. The alteration of the volume flow also changes the differential pressure and hence the β value too. However the volume flow has more influence on the cleanliness level.)

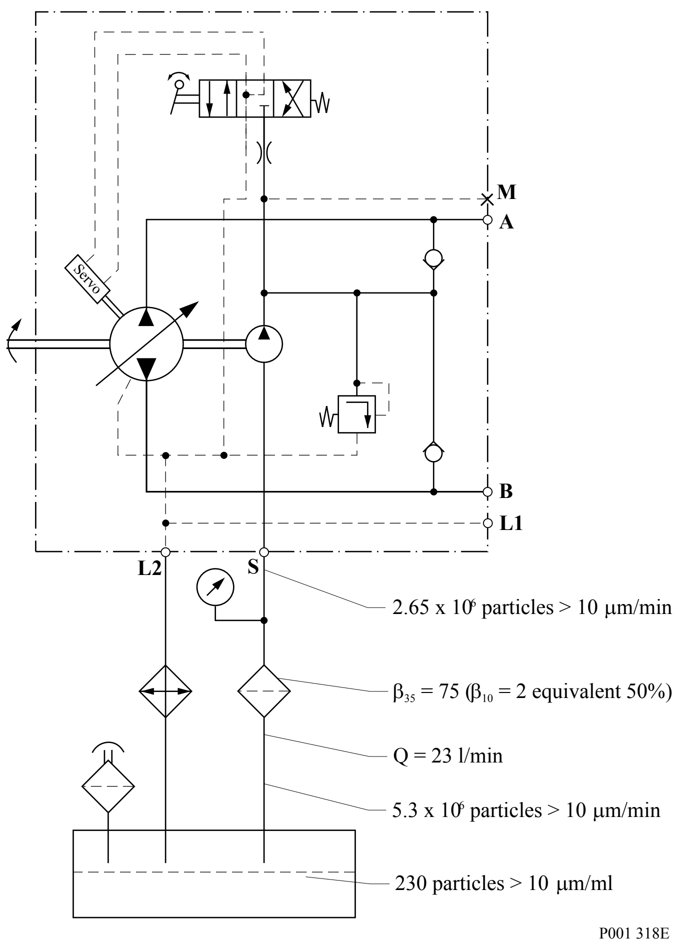
The flow volume cannot generally be selected freely since it is determined in a closed circuit by the size of the charge pump. However other operating factors take priority when the charge pump size is selected. In these cases, therefore, the β-value must be varied.

However, if the β-value is increased (different filter material) without the structural dimensions of the filter being increased, then the consequence is that:

Initial questions and answers

- the differential pressure rises (applies for new, uncontaminated filter element)
- the dirt absorption capacity drops (reduced service life)

Schematic of Series 90 variable pump with suction filter



Definition of β-ratio, efficiency, filter fineness

The β-ratio is defined in ISO 16 889-1999 Multi-pass test (old: ISO 4572-1982) as:

$$\beta_x = \frac{\text{Number of particles} > x\,\mu\text{m upstream of the filter}}{\text{Number of particles} > x\,\mu\text{m downstream of the filter}}$$

As a characteristic number the β_{10}-ratio is to be specified.

Example:

$$\beta_{10} = \frac{500 \text{ particles} > 10\,\mu\text{m upstream of the filter}}{10 \text{ particles} > 10\,\mu\text{m downstream of the filter}} = 50$$

This number defines the ratio of the number of particles before and after the filter. This means from 500 particles larger than 10 µm before the filter, 490 particles are retained in the element and only 10 pass through or from 50 particles before the filter, 49 are retained and only 1 passes through. This can be expressed as a filter efficiency:

Initial questions and answers

Filter efficiency:

$$\text{Filter efficiency} = \frac{500 - 10}{500} = \frac{50 - 1}{50} = 98\%$$

OR:

$$\text{Filter efficiency} = 1 - \frac{1}{\beta_{10}} = 1 - \frac{1}{50} = 98\%$$

This efficiency makes the filter performance more understandable. The table below shows clearly the relationship between β-ratio and efficiency. In practice the following term is often used: $\beta_X = 75$ (= 98,67% efficiency)

The observant reader will notice that increasing the β-ratio by 50% (from 50 to 75) the efficiency only increases by 0.67%, therefore β_X-ratios above 75% are not reasonable.

In some filter manufacturers catalogues you sometimes find β_X larger than 2000.

The real efficiency increase is shown in the table *β-ratio vs. efficiency*. The $\beta_{10} = 75$-ratio has been established as a standard. This specifies the particle size (indicated as "$_X$") were the β-ratio is equal to 75. This particle size is used to classify the filter fineness.

Example:

$\beta_{35} = 75$ equals a filter fineness of 35 µm

The term **absolute filter fineness** may not be used for this. Together with the β-ratio the related differential pressure at the filter element has to be specified. Unfortunately this is not always specified in the filter manufacturers catalogue.

β-ratio versus filter efficiency

β-ratio versus efficiency

β-ratio	Efficiency	β-ratio	Efficiency
1.0	0	6.4	84.4
1.1	9.1	6.8	85.3
1.2	16.7	7.0	85.7
1.3	23.1	7.2	86.1
1.4	28.6	7.4	86.5
1.5	33.3	7.6	86.8
1.6	37.5	7.8	87.2
1.7	41.1	8.0	87.5
1.8	44.5	8.2	87.8
1.9	47.3	8.4	88.1
2.0	50.0	8.6	88.4
2.1	52.4	8.8	88.6
2.2	54.4	9.0	88.9
2.3	56.5	9.2	89.1
2.4	58.3	9.4	89.4
2.5	60.0	9.6	89.6
2.6	61.5	9.8	89.8
2.7	62.9	10	90.0
2.8	64.3	11	90.9

Initial questions and answers

β-ratio versus efficiency (continued)

β-ratio	Efficiency	β-ratio	Efficiency
2.9	65.5	12	91.6
3.0	66.6	13	92.3
3.1	67.7	14	92.9
3.2	68.8	15	93.3
3.3	69.7	16	93.8
3.4	70.6	17	94.1
3.5	71.4	18	94.4
3.6	72.2	19	94.5
3.7	72.9	20	95.0
3.8	73.7	30	96.7
3.9	74.4	40	97.5
4.0	75.0	50	98.0
4.2	76.2	60	98.3
4.4	77.3	70	98.6
4.6	78.3	**75**	**98.67**
4.8	79.2	80	98.7
5.0	80.0	90	98.9
5.2	80.8	100	99.0
5.4	81.5	200	99.5
5.6	82.1	500	99.8
5.8	82.8	1000	99.9
6.0	83.3	2000	99.95
6.2	83.8	-	

Fluid cleanliness

Definition of cleanliness levels per ISO 4406

The cleanliness level of a hydraulic fluid is determined by counting number and size of particles in the fluid. The number of particles is defined as a cleanliness level according to ISO 4406.

Definition of cleanliness levels per ISO 4406

Number of particles per 100 ml	Number of particles per 1 ml	Cleanliness levels per ISO 4406
1-2	0.01 - 0.02	1
2-4	0.02 - 0.04	2
4-8	0.04 - 0.08	3
8-16	0.08 - 0.16	4
16-32	0.16 - 0.32	5
32-64	0.32 - 0.64	6
etc.	etc.	etc.
4×10^3 - 8×10^3	40 - 80	13
8×10^3 - 16×10^3	80 - 160	14
16×10^3 - 32×10^3	160 - 320	15
32×10^3 - 64×10^3	320 - 640	16
64×10^3 - 130×10^3	640 - 1300	17
130×10^3 - 250×10^3	1300 - 2500	18
250×10^3 - 500×10^3	2500 - 5000	19

The step to the next cleanliness level means double or half the number of particles.

The old ISO 4406-1987 defines the cleanliness level of particles larger than 5 µm and 15 µm. As an example: if 1910 particles/ml larger than 5 µm and 71 particles/ml larger than 15 µm are counted, the ISO 4406-1987 code level is 18/13.

In 1999 both, the definition for particle counting and the definition of ISO code was changed. The required cleanliness class definition is now determined by ISO 4406-1999. The allocated particle sizes are:

Comparison of old and new standard ISO 4406

Old ISO 4406-1987	New ISO 4406-1999
not defined	4 µm (c)
5 µm	6 µm (c)
15 µm	14 µm (c)

Please note, that “(c)” must be added to the new definition in order to identify that it is the new ISO 4406. The old method for particle counting may still be used.

The ISO 4406-1999 cleanliness class 22/18/13 means:

22 specifies the number of particles larger than 4 µm (c),
18 specifies the number of particles larger than 6 µm (c),
13 specifies the number of particles larger than 14 µm (c) related to 1 ml respectively 100 ml of the inspected fluid.

Measurements with the same fluid sample will result in the same cleanliness class for both methods as shown in *the table below*.

Fluid cleanliness

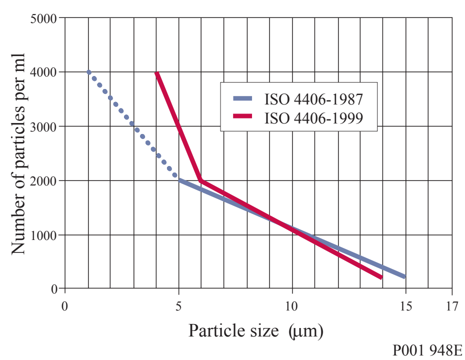
Number of particles per milliliter, particle count comparison

Particle size	1 µm	4 µm (c)	5 µm	6 µm (c)	6 µm (c)	15 µm
Not standardized	4000	-	-	-	-	-
Old ISO 4406-1987	-	-	2000	-	-	180
New ISO 4406-1999	-	4000	-	2000	180	-
ISO 4406 cleanliness class	19	19	18	18	15	15

The new method counts more smaller particles and less larger particles.
For better understanding please see the graph beside. This graph demonstrates the effect of the change to the new particle sizes 4 µm (c), 6 µm (c), and 14 µm (c).

Again, the actual number of particles of a sample is of course the same, only the counting method is different. Although it may look like, the new method does not allow more particles.

ISO 4406-1999 versus prior cleanliness classes



Together with this ISO 4406 change a new calibration standard ISO 11 171-1999 and a new Multi-pass test ISO 16 889-1999 for filters have been developed.

Comparison between old and new standards

Comparison between old and new standards		
Old standards	Test description	New standards
ISO 4402-1991	Automatic particle counter (APC) calibration	ISO 11 171-1999
ISO 4402-1991	Cleanliness code	ISO 4406-1999
ISO 4402-1991	Multipass test for filters	ISO 16 889-1999

Fluid cleanliness

The cleanliness of a fluid is one of the most important features to guarantee a satisfying performance of the hydraulic system. Contamination of a fluid with solid particles can lead to a failure of the complete hydraulic system by locking of the pistons or blocking the valves. Different systems have different sensitivity to solid contamination of the fluid, so different levels of fluid cleanliness are determined by ISO 4406. The determination of the cleanliness level is made by counting the particles, distinguishing the particle size.

Further information to fluid cleanliness, filter compatibility in a system and the cleanliness levels can be found in the document *Design Guidelines for Hydraulic Fluid Cleanliness, Technical Information*, **BC00000095**.

Fluid cleanliness requirements

To achieve the specified unit life a cleanliness level as shown below must be met. Fluid samples shall be taken either in the loop or at the entry to the pump, which is typically the suction line.

Fluid cleanliness

Fluid cleanliness requirements depends on the product and the products acceptable continuous or rated pressure limits.

Fluid cleanliness requirements according to product

Product	Required cleanliness class ISO 4406-1999	Curve in the diagram *Required fluid cleanliness*
Steering components with open center	22/20/17	A
Orbital motors	22/20/16	B
Steering components with LS and closed center	21/19/16	C
Proportional spool valves		
Axial & radial piston pumps and motors	22/18/13	D
Gear pumps and motors		
Cartridge and electrohydraulic valves	18/16/13	E

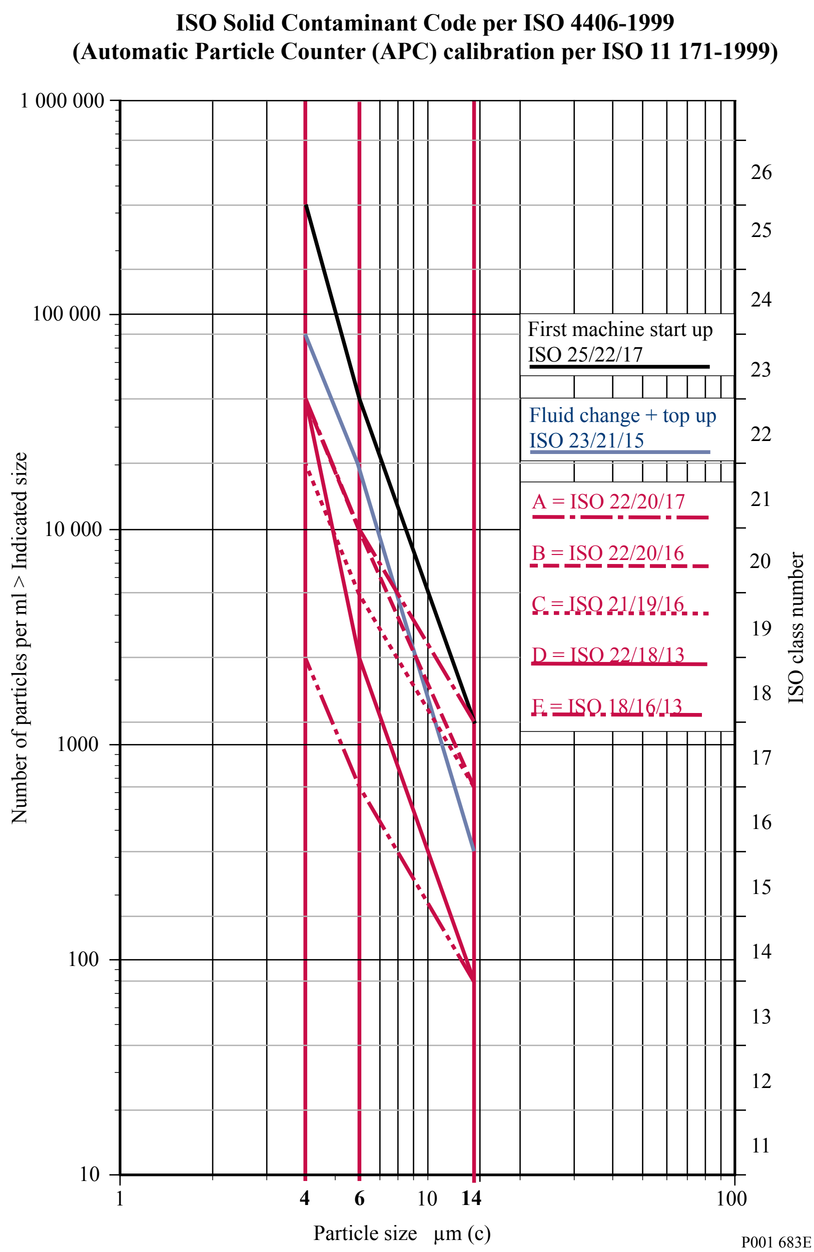
These cleanliness levels can not be applied for hydraulic fluid residing in the component housing/case or any other cavity after transport.

In general for fluid change and new fluid top up minimum cleanliness class 23/21/15 and for first machine start up at the factory minimum cleanliness 25/22/17 must be met if not otherwise specified. Exceeding these levels may result in start-up damage.

The before mentioned requirements reflect the experience gained from a broad range of applications. For very high lifetime requirements or contamination sensitive components (e. g. servo valves) better cleanliness levels are necessary.

Fluid cleanliness

Required fluid cleanliness diagram



Selection of an appropriate filter and filtration system

Example:

The design is explained below taking an SPV 9/075 with a charge pump volume of 17 cm^3 by way of example. A continuous pressure of 240 bar is assumed. Accordingly in section 3 the cleanliness class 18/13 to ISO 4406 results from curve **A**.

Closed Circuit

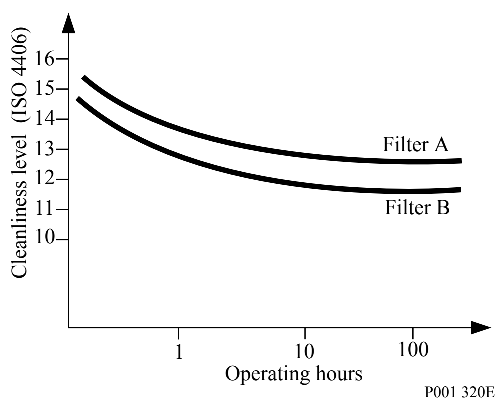
Design of a filter in the CC suction line

Examinations have revealed that a filter in the suction line with a $\beta_{35-\beta 45} = 75$ at a differential pressure of 0.25 bar achieves the required cleanliness level 18/13 under normal operating conditions. In some applications even better cleanliness levels are achieved. In order to assure that the cleanliness class is maintained we recommend that samples of the hydraulic fluid be drawn during the running-in time and that the particles be counted. A certain, constant cleanliness level will emerge during the operating time (see the illustration below).

An analogous graph can be drawn up for any particle size. The following reference can serve as a further guide.

A filter element with a $\beta_{10} = 2.0 – 1.5$ at 0.25 bar differential pressure (50% – 33% filtration efficiency for particles > 10 µm) generally reaches the above mentioned $\beta_{35} – \beta_{45} = 75$ value.

Cleanliness level evolving as a function of operating hours for particles larger than 15 µm



Design of a filter in the CC charge circuit

We recommend using filter elements with $\beta_{15} – \beta_{20} = 75$ ($\beta_{10} = 10$ corresponding to 90% filtration efficiency) at the differential pressure occurring in the application. A strainer with a mesh of 100 µm – 125 µm has to be used to protect the charge pump against coarse contamination. However the actual filtering work has to be performed by the filter in the charge circuit.

On the basis of what has been said so far *the question arises*: **Why is a higher filter fineness (β-value) necessary in a filter in the charge circuit?**

The answer is: The Multi-pass test per ISO 16 889 determines the β-values at constant volume flow and almost constant differential pressure increase. These optimal conditions do not exist in the charge circuit so that a reduced β-value sets in as a result of volume flow and pressure fluctuations. The filter industry and research institutes are in the process of developing practice-oriented test methods to solve this problem. Furthermore, the possible level of pressure fluctuations is much lower in a suction filter.

Moreover in certain circuits the filter is arranged behind the charge circuit pressure limiting valve, so that the whole charge pump volume flow does not constantly pass the filter. Related to the whole charge pump volume flow, an arithmetically lower β-value emerges here too. It is recommended that the cleanliness level actually existing or evolving in the course of time is determined here too.

Selection of an appropriate filter and filtration system

Open Circuit

Design of a filter in the OC suction line

In the open circuit, the whole main volume flow is taken from the tank; therefore, the suction filters must be adequately dimensioned in order to achieve appropriate differential pressures and service lives. Alternatively, a lower filter fineness can be selected, since a higher volume flow is available. For further information, please see *Design of a filter in the return line*.

Design of a filter in the OC return line

In the case of return line filters in open circuits, special attention must be paid to discontinuous volume flows through working cylinders with differing area ratio. Under certain circumstances it might therefore be advisable to select a larger filter than would be necessitated by the suction line alone. In any case a strainer with a mesh size of 100 – 125 µm should be provided in the suction line.

Filtration in OC with multiple pumps

A machine with several pumps using the same reservoir may use one filter only to save costs. Every circuit must be protected by a suction strainer with 100 –125 µm mesh.

This mesh equals theoretically: $\beta_{100\text{-}150} = 75$

This term should not be used for a screen. The off-line filtration may feed other functions and circuits like the steering equipment.

Recommendations for a new filter element

Recommendations for differential pressure: 0.1 bar (pressure drop) of a clean element

	In OC or CC suction line	In CC charge line	In OC return line
Viscosity	30 mm^2/s [141.2 SUS]		
Flow	charge pump displacement x rated speed		
β-ratios	$\beta_{35\text{-}45} = 75$ ($\beta_{10} \geq 2$)	$\beta_{15\text{-}20} = 75$ ($\beta_{10} \geq 10$)	

By-pass filtration

As in charge line. There will and must be exceptions to these recommendations to ensure an economic filtration system.

Dirt absorption capacity, maximum differential pressure

A further criterion for selecting the filter size is the dirt absorption capacity and differential pressure rise in the case of increasing contamination, see the illustrations below.

When the Multi-pass test to ISO 16 889 is performed, the dirt absorption capacity is also determined. It is important to distinguish between the apparent dirt absorption capacity, which is the amount of dirt added during the test, and the real dirt absorption capacity, which is the amount of dirt actually retained in the filter.

The following equation applies:

Added dirt quantity (apparent dirt absorption capacity) minus dirt quantity remaining in the oil is the actual dirt absorption capacity.

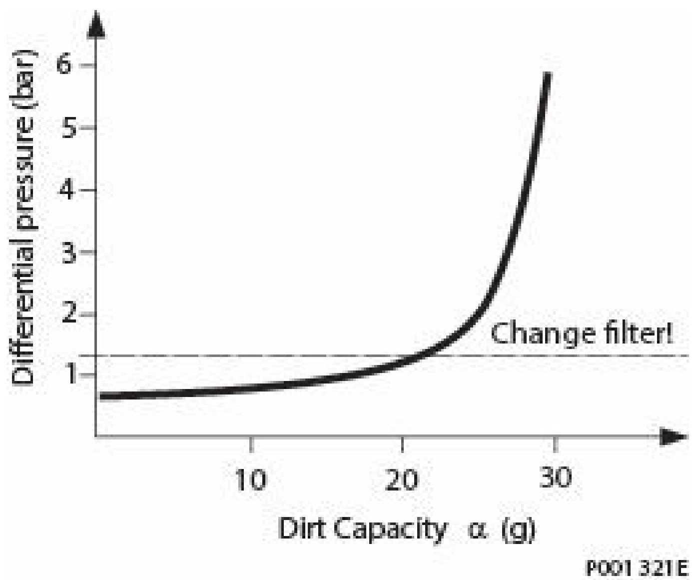
The differential pressure starts in an approximately linear manner before rising exponentially.

Once this zone is reached, it is time to change the filter, since a little dirt means a large increase in the differential pressure.

In the case of the above filter element, the contamination indicator should respond either optically or electrically at approximately 2.2 bar and indicate that it is time to change the elements concerned.

Selection of an appropriate filter and filtration system

Rise of the differential pressure when dirt is added



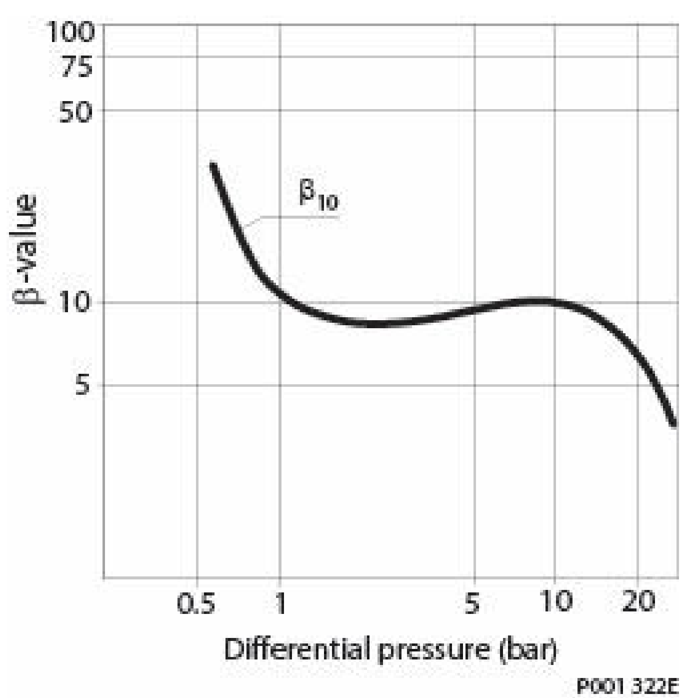
Depending on the filter material, certain maximum differential pressures must not be exceeded since the filter material may be damaged and dirt already retained will be released again, i. e. the dirt is pumped through.

The curve of the β-value versus the differential pressure shows this (see the illustration *Retention rate as a function of the differential pressure*).

If it is expected that the filter element will not be changed in time before the rupture point is achieved, a bypass valve must be installed.

A bypass valve must also be provided if the differential pressure rises to an inadmissible level during cold starts, which is usually the case.

Retention rate as a function of the differential pressure



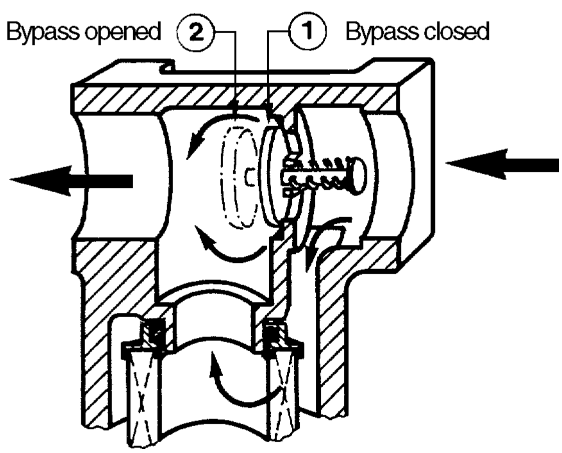
Selection of an appropriate filter and filtration system

Why a bypass?

During operation the differential pressure at the filter element rises due to contamination. Without a bypass, especially during cold starts, this would lead to demage to the filter element or collapse of the support elements. This can be effectively prevented by the use of a bypass.

Although the effective filter efficiency is reduced by the short opening of the bypass during cold starts, the hydrostatic unit is not immediately damaged as a result of this.

Function of a bypass



The cleanliness level simply deteriorates as a function of the time during which the bypass is in operation and as a function of the newly generated particles. Working with an open bypass for several hours or days should be avoided. This condition can be monitored reliably with a contamination indicator (see *Contamination indicator* on page 16). The system operator thus determines the service life of the hydrostatic units and the rest of the system by regularly checking the contamination level of the filter and changing the filter elements in time.

It is important to understand that if used as explained above, a bypass is always better than the sudden release of a particle or a dirt cloud due to damage to an element whereby the cloud is passed through the whole system (including the high-pressure circuit) and finally lands in the tank after irreparable damage is sustained by the sliding parts. If there is no contamination indicator either, this damage is not noticed and it may be that the system is operated for a long time with this unintentional **bypass** (after the element has been destroyed!) until overheating caused by reduced efficiency of the hydrostatic units is recognized. This then turns out to be much more expensive than the additional bypass and the contamination indicator would have been (see *Contamination indicator*).

A bypass should be arranged as shown above or even further away from the element if the design allows this. Under certain circumstances it may even be a design advantage if the filter elements are to be bolted directly on to the pump (charge circuit filtration).

Caution

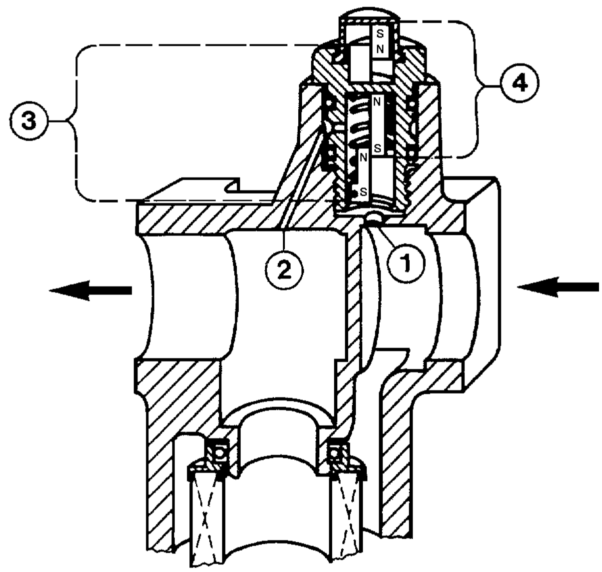
A bypass may never be situated in the base of the filter element since the dirt settles in this area and is flushed into the system again.

Contamination indicator

The contamination indicator responds when a predetermined differential pressure occurs as a result of growing contamination of the filter element. An optical signal appears, or an electrical contact is energized.

Selection of an appropriate filter and filtration system

Function of the indicator (differential pressure)



1. Pressure before the filter element
2. Pressure behind the filter element
3. Position of the magnets in a clean element
4. Position of the magnets in a contaminated element

Air breather

Sufficient attention must also be devoted to **air breathers**, since a considerable portion of the contamination makes its way into hydraulic systems via unsuitable ventilation systems. Design measures such as pressurizing reservoirs are often not economically efficient by comparison with today's air breathers.

Under certain circumstances it may be necessary to observe the Pressurized Container Regulations if the pressure content product derived from tank volume times pressure exceeds a certain value.

Unfortunately there is no standard for air breathers corresponding to the Multi-pass test to ISO 16 889. The filter fineness quoted by the manufacturer of the air breathers has to be relied on. This does not permit comparisons between manufacturers **A** and **B** since, as already mentioned, there are no standardized tests.

Generally speaking the fineness of the air breathers must be equivalent to or better than the "working filters" present in the system.

Therefore only the $\beta_x = 75$ values and the given filter fineness of the air breathers can be taken as standard values.

What is to be Done if the Required Cleanliness Class is not Achieved?

A brief reminder

It was explained before that the cleanliness level is influenced by:

- the β-value (filter fineness, filtration ratio)
- the volume flow through the filter

If the required cleanliness level is not achieved using the 17 cm^3/U charge pump and the $\beta_{10} = 75$ filter, it is not necessarily expedient to use a larger charge pump. This may necessitate a larger filter since the differential pressure more quickly reaches the limit of p = 0.25 bar (risk of cavitation) with a clean filter element, which leads to insufficient service life of the element. The energy balance also deteriorates as a result of the higher power loss.

Selection of an appropriate filter and filtration system

In this case filters with a higher β-value must be used. However, since the higher β-values generally also involve higher differential pressures, it is often also necessary to move the filter to the charge circuit. If the filter elements are designed accordingly, higher differential pressures are admissible here so that the overall dimensions of the filter can be reduced - representing an installation advantage. It must also be clarified and checked to what extent new contamination can be reduced and prevented.

It was explained before that inadequate ventilation facilities are a cause of fresh contamination. An improvement of the cleanliness level can often be achieved by using ventilation filters with better filter fineness, especially for applications with working cylinders with differing area ratios.

For the design of the ventilation filter the differential pressure (caused by the differential air volume flow) must be kept as low as possible in order to prevent cavitation in the suction area of the pumps. It should also be checked whether unsuitable piston rod seals or leaks are the cause.

Dirt which does not enter the system or is not caused by wear need not be removed by filtration.

Why Loop Flushing?

Filtration is intended to remove contamination from the hydraulic fluid. For this, however, the contamination must be passed to the filter element. In a closed circuit without circuit purging, existing contamination can only be removed from the system with the oil leaking from the pistons, the control valve etc. Since only particles smaller than the leak gap width can leave the closed circuit, the remaining particles stay in the circuit and can lead to erosion damage in areas with high flow velocities.

This can be avoided by circuit purging, i. e. by forcing 5–6 l/min from the low pressure circuit via an spool valve and a purge relief valve.

The contamination flushed out in this way (including particles larger than the leak gap width) can now be passed to the filter element installed in the system and be removed.

Taking of Fluid Samples

Fluid samples

Fluid samples must be drawn very carefully into appropriate bottles to prevent extraneous dirt from, falsifying the sample result.

The sample bottle should contain a label with the following information:

- Sample number
- Source of sample
- Sampling method
- Date and time of sampling
- Nature of fluid
- Comments/remarks if necessary

Sampling according to ISO 4021 from a system in operation

Sampling points should be provided at the design stage of the hydraulic installation. They should be arranged in the turbulent main flow.

Caution

Take precautionary measures to protect personnel and equipment.

Sampling device

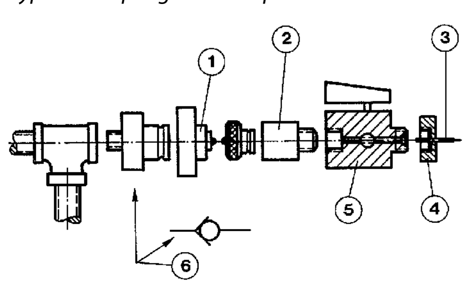
- If turbulent flow conditions prevail in the main flow, a typical sampling device

  (as shown in *Typical sampling device in practice* on page 19).
- A quick fastening coupling 6 is permanently attached to the opening through which the sample is to be withdrawn
- A dust protection cap 1 is provided for the part 6
- The remaining part of the unit 2-5 is secured for sampling
- The inner diameter and length of the capillary tube are selected in agreement with the desired sample quantity
- Capillary tubes with an inner diameter of less than 1.25 mm may not be used.

  Other cross-sectional forms (e. g. rectangular) can be used, provided that the smallest internal dimension is not less than 1 mm
- The end of the capillary tube is sharpened and deburred in order to facilitate the subsequent penetration of the film which covers the opening of the sample bottles
- If no turbulence can be guaranteed in the flow, a device for generating turbulence must be used,

  e. g. a turbulent sampler

Typical sampling device in practice



1. Dust protection cap
2. Valve without check device
3. Capillary tube for drawing off fluid

Taking of Fluid Samples

4. Cover cap with capillary tube
5. Ball valve
6. Check valve, outer part for quick fastening

Sampling method

- Ball valve 5 is opened
- Allow at least 200 ml fluid to flow through the sampling device before collecting the fluid
- Without closing the ball valve, place the sample bottle in the position for collecting the fluid
- Pierce the protective film covering the bottle opening with the sharp end of the capillary tube
- Draw a sample of not more than 90 % and not less than 50 % of the bottle volume.
- When a sufficient sample quantity has been collected, remove the sample bottle before stopping the flow with the ball valve
- Seal the sample bottle immediately after withdrawing the capillary tube
- If a sampling device with quick-fastening coupling is used, the removable parts of the sampling device are to be dismantled and all other fluid traces are to be removed by flushing with a suitable solvent
- Immediately after dismantling the dust protection cap is replaced on the permanently mounted part of the quick fastening coupling.

Sampling from a tank according to CETOP RP 95 H

Sampling from the tank should only be carried out if it is not possible to sample from the main flow. Clean the outer surface of the tank around the places from which the sample is to be drawn.

Sampling:

The fluid in the tank should be mixed well in order to ensure that the sample is typical. To this end warm up the system by running it under operating conditions. Then draw a sample (at least 150 ml) with the aid of a pipette or a cleaned disposable syringe. Pass the pipette about half way down into the fluid.

Ensure that the pipette does not touch the side walls of the tank or come too close to the bottom. Fill the contents of the pipette into the sample bottle and seal this carefully. Cover the tank again or close it with clean covering film if further samples are required.

Working hints

The frequency and intensity of the maintenance work to be performed depend on the burden generated by environmental influences and on the workload.

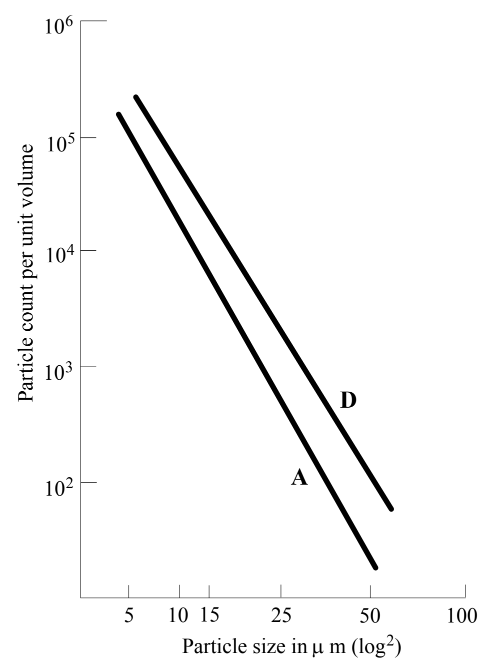
Special attention must always be paid to the operational suitability and cleanness of the hydraulic fluid.

Scavenging and running in

Before a hydraulic system is commissioned, the assembly dirt must be removed. This is best done by flushing the whole installation with a portable filter unit. Mineral oil (or another medium compatible with the hydraulic fluid to be used subsequently) is pumped through the whole system or parts of the system at the highest possible flow velocity. The assembly dirt is filtered in the filter unit.

During this process the elements of the built-in filters are to be removed. Small or less sensitive systems can also be scavenged with the built-in filters during the running-in process. It must be ensured that the system is run without load but with a displacement which is gradually increased up to maximum.

The illustration beside shows the relation between the design-specific, admissible cleanliness level and the actual cleanliness prior to commissioning.
Typical relation between the design-specific, admissible cleanliness **level A** and the actual cleanliness level prior to commissioning **level D**.
It is vital that the system be flushed and run at low pressure until the required cleanliness level is achieved.



P001 326E

Monitoring of contamination

Permanent

Every filter should be equipped with an optical/electrical indicator of the contamination level at the filter. In this way it is possible to establish at any time whether there is still any dirt absorption capacity or whether the elements have to be changed. The checks should be carried out daily once the operating temperature is achieved.

If a contamination indicator with electrical signal device is used, the selected signal is emitted at operating temperature when the filter element is contaminated. During the warming up phase a "contaminated" signal is nearly always emitted due to the higher differential pressure unless the contamination indicator is equipped with a signal cut-out for the cold start phase.

Cyclical

With regular monitoring, filters are suitable as wear surveillance elements for the components of the hydraulic system. If the operator keeps a log of filter changes, it can be assumed in the event of shorter changing intervals that the wear of the system components is increasing. The origin of the main contamination can be ascertained by analysing a fluid sample and the contaminated element. A

Working hints

comparison of the results with the materials used allows preventive maintenance before a complete failure interrupts production or operation. Adherence to the required cleanliness level is checked by measuring the contamination and this ensures that no premature wear or failure occurs.

These samples must be drawn at specially designed sampling points as explained before.

Topping up hydraulic fluid

Any fluid used to top up losses should always be poured in via a fine filter in order to maintain the cleanliness class. Where appropriate facilities are available, the return flow filter can be used. It is advisable to provide a permanent connection which should be included in considerations at the design stage. Any opening of the tank/reservoir for maintenance purposes (topping up hydraulic fluid, sampling, changing filter elements in built-in tanks etc.) should always be avoided as far as possible by an expedient design. Even though some ventilation filters have a so-called filling screen (mesh width > 100 µm), this still does not afford any protection against the penetration of particles of the order of magnitude of 10 – 100 µm.

Changing the element

If the contamination indicator shows a contaminated element, this must be changed without delay due to the high rate of increase of pressure drop as the element becomes more contaminated. Extreme care must be taken when changing the element.
The operating instructions must be followed precisely.

The following standard values apply for filter maintenance intervals:

1. 24 hours after commissioning the system
2. After the running-in period (50 - 100 hours of service)
3. Normal maintenance after 300 - 500 hours of service

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