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DGUV-Information

Filtration of hydraulic fluids

in hydraulic control systems

Issue 07/2016 Translation of the German version. FB HM-082

The use of filters for effective particle separation in hydraulic systems is required to ensure the operating function of the components and therefore the entire system.

The filters also ensure minimised wear of the hydraulic components, long component lifetimes and long maintenance intervals.

Filters therefore play a crucial role in ensuring that systems can be operated reliably, economically and safely, with high availability and low maintenance.

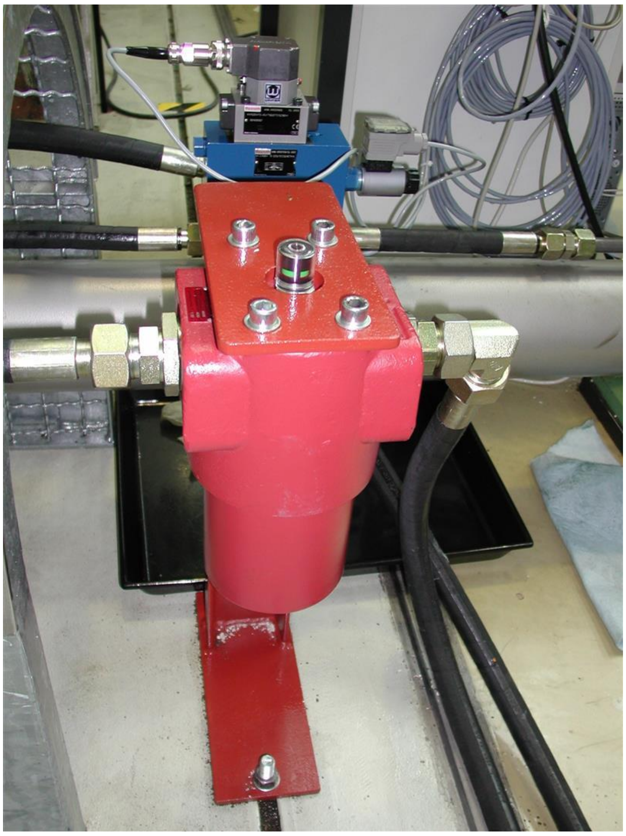

Figure 1: Filter on a hydraulic power unit

1 Hydraulic equipment

Devices for maintaining the required cleanliness class of used operating fluids have always been among the necessary equipment for machines with hydraulic control systems (see DIN EN ISO 4413 [1], clause 5.4.5.3).

On machinery, the filters must be fitted with a device that indicates when the filter requires maintenance (see DIN EN ISO 4413, clause 5.4.5.3.2.2). The indicator (see Figure 1) must be clearly visible to the operating and maintenance personnel (see DIN EN ISO 4413, clause 5.4.8.5). If this requirement cannot be fulfilled, maintenance intervals for the filter must be specified in the machine operating instructions.

Note:
The provision of the filter with a switching element (pressure sensor), in conjunction with signal analysis and an appropriate indicator, enables the correct maintenance measures to be carried out.

Filters, whose filter elements cannot withstand the differential pressure in its part of the system without sustaining damage, must be fitted with a bypass valve. Contamination in the bypass flow downstream of the pressure filter shall not cause a hazard to employees (see DIN EN 4413, clause 5.4.5.3.2.5).

In terms of the safety-related parts of the hydraulic control system of a machine, the filters - as devices that ensure the "condition of the operating fluid" – belong to the "fundamental and proven safety principles" according to DIN EN ISO 13849-2 [2], Annex C.1 and C.2.

2 Basics of filtration

2.1 Contamination

Contaminants in the operating fluid of a hydraulic system are generally referred to as dirt or contamination.

There are three types of contamination:

- Solid contamination
- Liquid contamination
- Gaseous contamination

Some examples of solid contaminants or particles are rust, swarf, fibres, seal abrasion, rubber particles, paint particles, dust and sand. Solid contamination also includes oxidation products which are caused by ageing of the operating fluid.

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A typical liquid contamination is water and also mixing with other operating fluids or lubricants. Gaseous contamination is primarily air in the operating fluid.

There are a number of possible causes for contamination in the system, including:

2.1.1 Initial contamination

There are various system components, such as valves, cylinders, pumps, tanks or pipelines, which could contain contamination in the form of production residues. In addition, other residues are produced in the system during assembly, such as welding beads, metal chips, textile fibres, paint particles, sand or dust. The system must be flushed prior to commissioning to wash out these residues. Filtration of the new hydraulic fluid when filling the system is also required. The initial contamination of new hydraulic fluids may be higher than is permitted by component manufacturers to ensure safe operation of the hydraulic components, in particular due to storage of the operating fluid in tanks or barrels.

2.1.2 System contamination

During operation, the system itself produces contaminants due to component wear, corrosion, ageing, and the operating fluid mixing with other liquids. The more dirt there is in the system, the more severe the wear of the components. Without filtration the dirt content would continue to rise.

2.1.3 Contamination from external sources

Dirt can also enter the system from the outside, in particular due to tank ventilation, via the piston rod of a cylinder, via damaged seals or due to tool change on mobile systems. Dirt can also enter the hydraulic circuit from the outside due to interventions to the system, for example during repair or maintenance procedures.

2.2 Cleanliness classes

The level of contamination in operating fluids is defined by cleanliness classes. The key classifications are done in accordance with standards ISO 4406 [3] or SAE AS 4059 [4].

In order to determine the cleanliness level according to ISO 4406, the particles in 100 ml fluid are counted, sorted according to size and quantity, and divided into particle classes. The determined cleanliness class is then indicated by a combination of three numbers (e.g. 20/18/15). The three values represent the number of particles > 4 µm, > 6 µm and >14 µm, respectively. The ISO code is reproduced in part in Table 1.

Example:

- 980,000 particles > 4 $\mu m_{(c)}$ → 20
- 145,000 particles > 6 $\mu m_{(c)}$ → 18
- 21,000 particles > 14 $\mu m_{(c)}$ → 15

➔ Cleanliness class 20/18/15

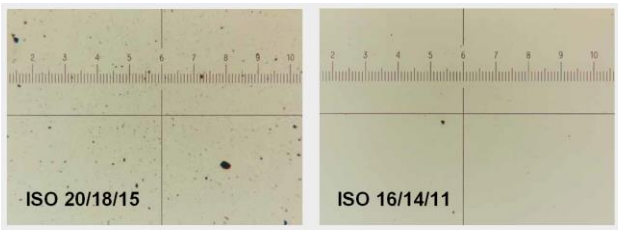
Many manufacturers of hydraulic components specify the cleanliness class required for safe operation in the data sheets. The cleanliness class required for the entire hydraulic system depends on the component most sensitive to contamination. Non-compliance with the specified cleanliness class may lead to early component

ISO Code	Particle count per 100 ml	
to ISO 4406	from	to
5	16	32
6	32	64
7	64	130
8	130	250
9	250	500
10	500	1,000
11	1,000	2,000
12	2,000	4,000
13	4,000	8,000
14	8,000	16,000
15	16,000	32,000
16	32,000	64,000
17	64,000	130,000
18	130,000	250,000
19	250,000	500,000
20	500,000	1,000,000
21	1,000,000	2,000,000
22	2,000,000	4,000,000
23	4,000,000	8,000,000
24	8,000,000	16,000,000
25	16,000,000	32,000,000
26	32,000,000	64,000,000
27	64,000,000	130,000,000
28	130,000,000	250,000,000

Table 1: Cleanliness classes according to ISO 4406 (excerpt)

failures. Moreover, this shortened service life of the components gives rise to increased maintenance costs. Therefore, the specifications with regard to the cleanliness of the operating fluid must be complied with and sufficient filtration must be provided.

By way of example, Figure 2 shows the contamination of a new operating fluid in delivery condition and in the cleanliness required for application.



Operating fluid as delivered — Required cleanliness

Figure 2: Examples of contamination

2.3 Types of filters

In principle, hydraulic filters can be distinguished according to their function and location in the hydraulic system.

There are various types of filters depending on the installation situation. Figure 3 shows examples of these filter types and where they are installed.

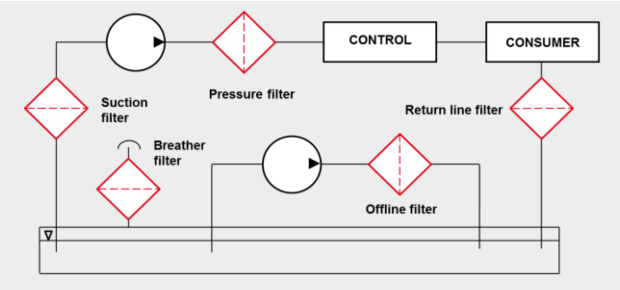


Figure 3: Diagram of filter types

Protective filters are usually installed upstream of components which are sensitive to contamination (e. g. pumps, servo valves). They protect the components from coarse particles.

Working filters (system filters) are used to clean the operating fluid of particles and ensure the necessary cleanliness class.

2.3.1 Suction filter

Suction filters are typical protective filters. These filters are installed between the tank and hydraulic pump so as to protect the pump from coarse contamination. They can be installed inline, at the intake port in the tank or below the tank. Due to the risk of pump cavitation, relatively coarse filter materials with a filtration rating of > 25 µm are often used. For this reason, suction filters alone are usually not suitable for ensuring the component protection necessary for the reliable operation of the system.

2.3.2 Pressure filter

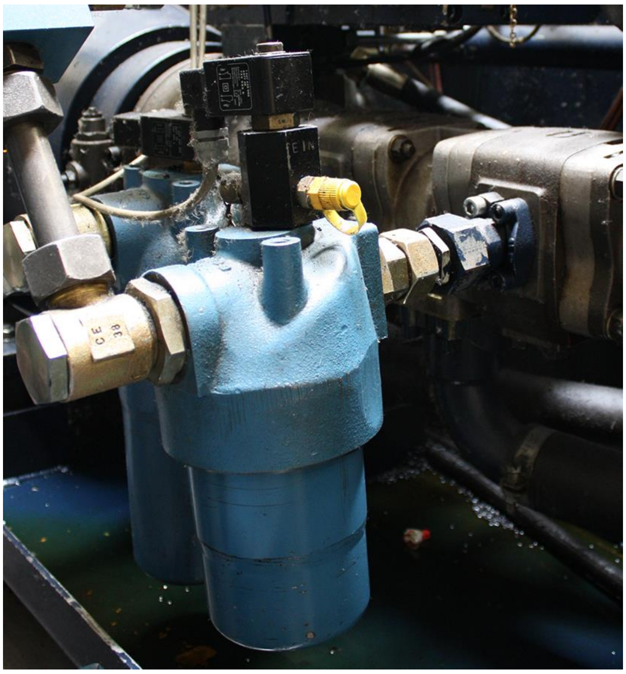


Figure 4: Pressure filter with differential pressure sensor

Pressure filters (Figs 1, 4) are fitted after the system pump. They are selected depending on the system pressure and the flow rate in the pressure line. They are particularly suitable for protecting sensitive components. High pressure filters must be able to constantly withstand the maximum system pressure. Pressure filters must always be fitted with a clogging indicator. If this is not possible, a scheduled filter change must be specified in the operating instructions.

Upstream of particularly critical components (e. g. servo valves), only filters without bypass valves should be used. Such protective filters must be fitted with a filter element which is capable of withstanding even higher differential pressures (see DIN 24550-1 [5]).

2.3.3 Return line filter

This type of filter can either be installed in the return line to the hydraulic tank, or as a tank-mounted filter. All of the return flow from the system is filtered before it flows into the tank. When selecting the correct filter size, the maximum possible return flow rate must be taken into account. If dangerous malfunctions could occur as a result of excessive differential pressure in the return line filter, this filter must be fitted with a bypass valve. Figure 5 shows different types of return line filters.

Figure 5: Return line filters on a hydraulic tank

2.3.4 Offline filter

Additional offline filters (see figure 6) are increasingly used in hydraulic systems with heavy loads to avoid the accumulation of fine particles. In contrast to main line filters, only a small part of the whole flow in the system is filtered by offline filters.

Figure 6: Offline filter system

Excellent operating fluid cleanliness levels can be achieved through continual filtration, regardless of the operating cycle of the machine and with the use of ultra-fine filter elements. Offline filter systems can be used in addition to main line filters.

2.3.5 Breather filter

Tank breather filters prevent contamination from the ambient air entering the hydraulic circuit and are therefore some of the most important, yet usually neglected filters. Ideally, the breather filters should be of at least the same filtration rating as the finest filtration unit in the system. In applications where a high amount of dust is expected, the breather filter should be installed on a pedestal. This prevents the filter from getting covered with dust and ensures no dust is drawn in.

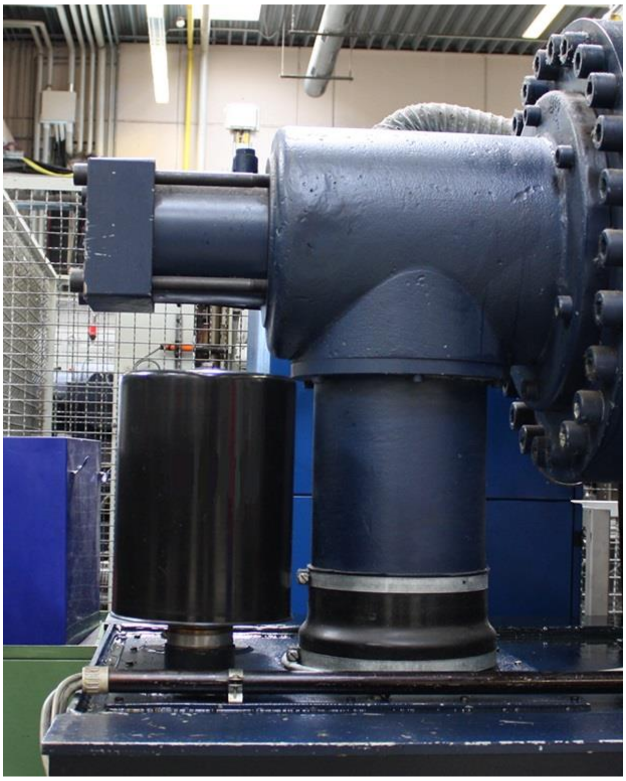


Figure 7: Breather filter on pedestal

2.4 Filter characteristic values

The efficiency of a filter is mainly determined by three parameters: the contamination retention capacity, filtration rating and differential pressure. All three values influence each other. A high-quality filter element is characterised by the fact that it combines these three factors in an optimum ratio, i.e. it achieves the required separation values with maximum contamination retention and minimum differential pressure. The most important test for evaluating the performance of filter elements is the multi-pass test according to ISO 16889 [6]. Further filter parameters which, depending on the application, can influence the filter selection are the collapse and burst-pressure rating, flow fatigue strength, media compatibility and cold-start performance.

2.5 Filter selection

The most important task for a filter is to ensure the required oil cleanliness in order to protect the components used from wear and failure. The specified cleanliness classes and possible contamination sources define the filtration rating required. The installed components which need protection determine the installation location and function of the filter (working or protective). The size of the filter is determined according to the maximum flow rate. Other system parameters which affect the choice of filter are operating temperature, maximum operating pressure, permissible differential pressure at the filter, oil type/viscosity, cold-start temperature, ambient conditions, filter design (e. g. change-over) and the theoretical time it takes for the operating fluid to complete one cycle.

3 Consequences of inadequate filtration

If the operating fluid of a hydraulic system is not filtered adequately, this could have a significant impact on the entire system.

3.1 Damage due to contamination

The wear of individual components and the entire system is significantly accelerated. Material on the surface of components is worn down due to the effects of abrasion and erosion. As a result, the tolerances change and this leads to leakage. In addition, the efficiency is reduced and the service life of the components is shortened considerably. Component damage can lead to functional system failures (complete system downtime) and even dangerous failure of the hydraulic control system (e. g. jammed valve).

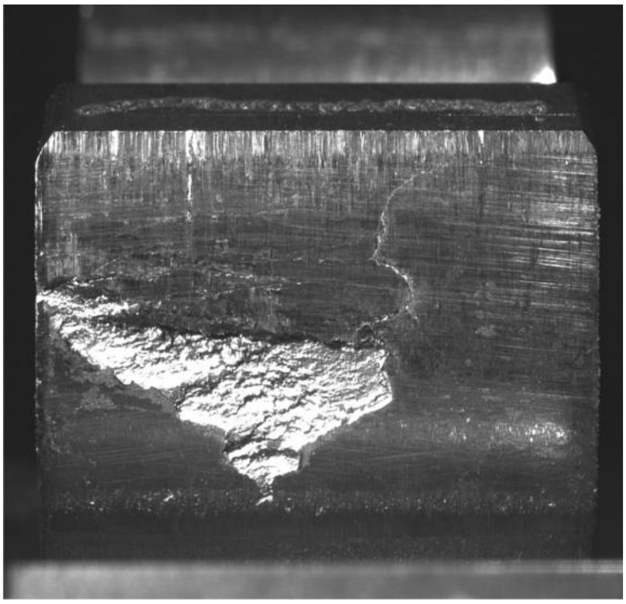


Figure 8: Tooth flank damage

The extent of component damage depends on the material of the contamination. The harder the particles, the more extensive the damage. The size and number of particles is also significant. The higher the operating pressure, the harder the particles are pressed into the lubrication gap and the more damage they cause. Figs 8 and 9 show typical damage patterns on a gear tooth flank and on a damaged valve spool, both caused by excessive contamination in the lubricant. Further information about the ageing process of hydraulic valves can be found in the BIA Report 6/2004 [7].

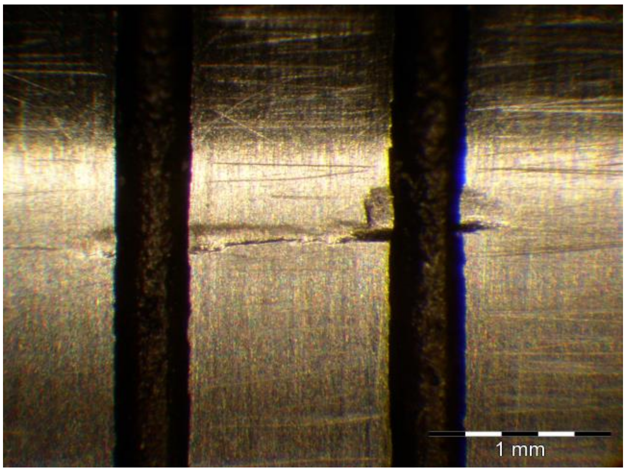


Figure 9: Microscopic image of a valve spool operated under poor conditions

3.2 Preventing damage

Severe contamination of the hydraulic fluid not only causes increased wear and shortened service life of the components; insufficient filtration also increases accelerated oil ageing and loss of efficiency. Most hydraulic system failures can be traced back to contaminated operating fluid.

Effective filtration is therefore essential for ensuring the required oil cleanliness and for operating the hydraulic system reliably and safely.

Adequate filtration of hydraulic fluids reduces the efforts for system and hydraulics maintenance (spare parts purchase and storage as well as standby and deployment of maintenance personnel.

Note:

The expert committee woodworking and metalworking (FB HM) has been advised, that the use of modern, environmentally friendly hydraulic oils, together with the trend towards ever more compact systems and finer filtration, may lead in some cases to problems of electrostatic charge and discharge. Zinc and ash-free oils in particular often have low electrical conductivity. If such a low-conductivity oil flows through a conventional filter element, the element and oil can become electrostatically charged and electrostatic discharge may occur in the system or externally. Operators of hydraulic systems should first contact the system's manufacturer in case of problems of electrostatic discharge. Some filter manufacturers provide technical solutions.

4 Operational filter change

Operators of machines with hydraulic control systems must regularly check the hydraulic filters, including any offline filters, and replace them in accordance with the manufacturer's specifications and the maintenance schedule or when dictated by the clogging indicator.

Note:

The inspection and replacement intervals for the filters must be adhered to!

When changing filters be sure to reduce pressure, watch out for scalding from hot hydraulic oil, take care to avoid the ingress of contamination and water, note the condition of the seals and bleed the system. Further safety information for carrying out maintenance work can be found in the DGUV Information 209-070 [8].

In some cases - e. g. with increased failure of hydraulic components - it may be expedient to discuss the improvement of the present filtration equipment of a machine with the machine's manufacturer or a filter specialist and, if necessary, to revise the filtration concept.

When retrofitting additional filters, ensure their installation outside the hazard zones where they are easy to maintain as well as compliance with the requirements of DIN EN ISO 4413 (e. g. maintenance indicator).

5 Summary and limits of application

This DGUV-Information is based on expert knowledge gathered by the expert committee woodworking and metalworking, subcommittee machinery, systems and automation in the field of hydraulic equipment of machines and systems.

The present DGUV-Information has been developed by the statutory accident insurance' expert committee on hydraulics and pneumatics in cooperation with the „Institut für Arbeitsschutz (IFA) of Deutsche Gesetzliche Unfallversicherung (DGUV). It is particularly intended as information to manufacturers and users of machinery for specifying and implementing filter systems in hydraulic control systems of machinery and systems, which belong to the scope of the European Machinery Directive [9].

The particular specifications for other applications (in mining or similar) have to be taken into account.

The provisions according to individual laws and regulations remain unaffected by this DGUV-Information. The requirements of the legal regulations apply in full. In order to get complete information, it is necessary to read the relevant regulation texts and the current standards.

The expert committee woodworking and metalworking is composed of representatives of the German Social Accident Insurance Institutions, federal authorities, social partners, manufacturers and users.

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Further DGUV-Information and information sheets of the expert committee woodworking and metalworking (Fachbereich Holz und Metall) can be downloaded from the internet [10].

As to the aims of the DGUV-Information, refer to DGUV-Information FB HM-001 „Aims of the DGUV-Information published by the expert committee woodworking and metalworking".

German Bibliography:

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[2] DIN EN ISO 13849-2 Sicherheit von Maschinen - Sicherheitsbezogene Teile von Steuerungen - Teil 2: Validierung, 2013-02, Beuth-Verlag

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[6] ISO 16889, Fluidtechnik - Filter - Prüfverfahren mit Mehrfachdurchgang zur Bestimmung der Filterleistung eines Filterelementes, 2008-06, Beuth Verlag, Berlin

[7] BIA-Report 6/2004 „Untersuchung des Alterungsprozesses von hydraulischen Ventilen“, Institut für Arbeitsschutz der DGUV (IFA), 53754 Sankt Augustin.

[8] DGUV Information 209-070 „Sicherheit bei der Hydraulik-Instandhaltung“ (bisher: BGI 5100), Ausgabe 2014-01, Fachbereich Holz und Metall FB-HM der Deutschen Gesetzlichen Unfallversicherung DGUV, Berlin,

[9] Richtlinie 2006/42/EG (Maschinenrichtlinie) Amtsblatt der Europäischen Gemeinschaften Nr. L 157/24 vom 09.06.2006 mit Berichtigung im Amtsblatt L76/35 vom 16.03.2007.

[10] Internet: www.dguv.de/fb-holzundmetall Publikationen oder www.bghm.de Webcode: <626>

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