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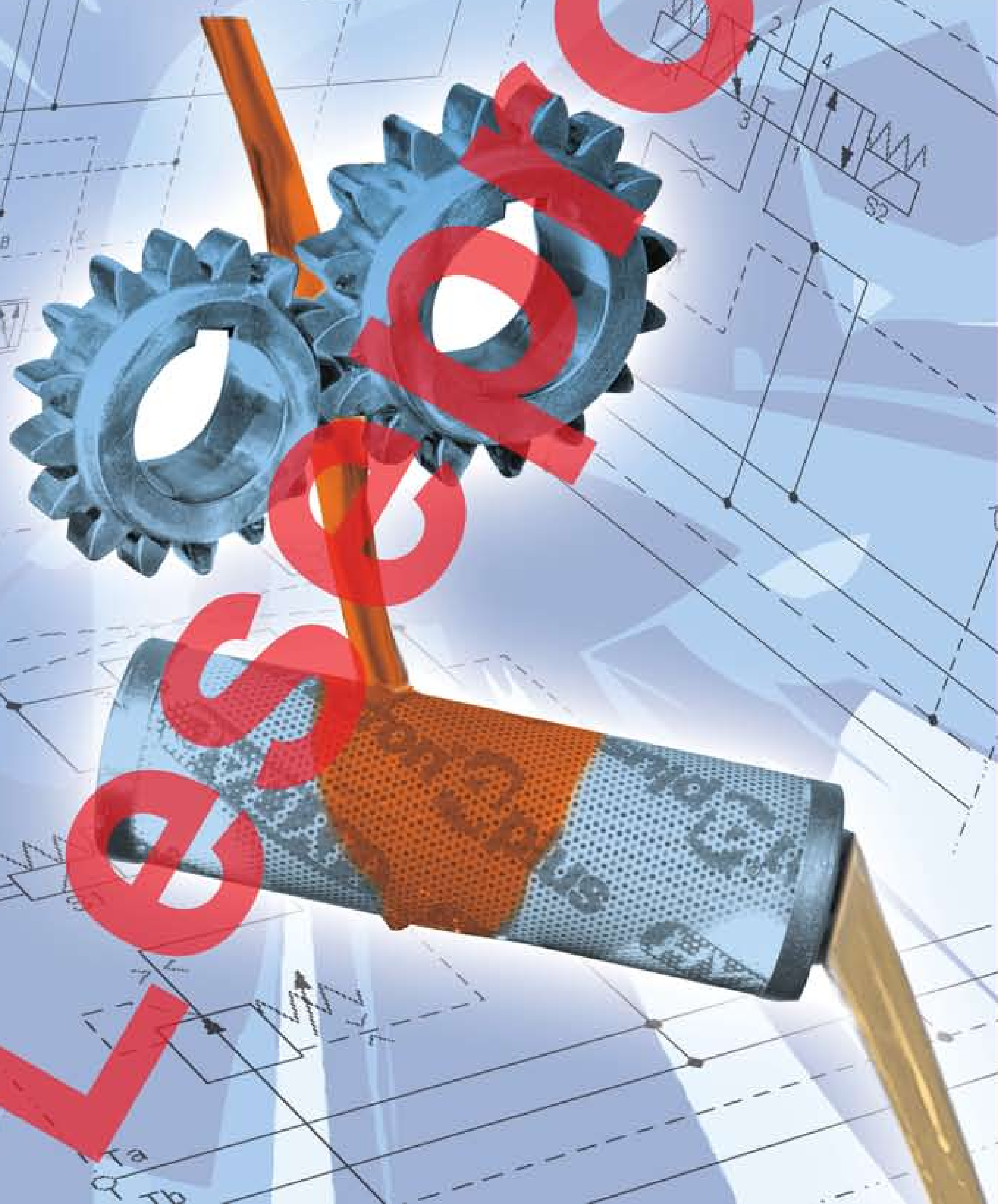
Filtration of Lubricating Oils and Hydraulic Fluids



HYDAC TRAINING CENTER Filtration of Lubricating Oils and Hydraulic Fluids

Filtration of Lubricating Oils and Hydraulic Fluids

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I Filtration of lubricating oils and hydraulic fluids

1 Overview

The use of filters with effective **particle separation** in lubrication and hydraulic systems is required in order to guarantee the operating function of the components and hence the entire system. Moreover, the filter ensures that the wear on the components is minimized and that both prolonged component lifetimes and extended maintenance intervals can be realized.

Filters therefore play an important role in ensuring that systems operate:

- Reliably;
- with high and long availability;
- with low maintenance and costs;
- and economically.

The demands on the machine manufacturer with reference to:

- extended warranty periods

and

- greater system availability

are reduced through the use of highly-effective filter systems.

When dimensioning ball and roller bearings with reference to the lifetime of the bearings, contamination of the fluids is a major factor in the calculation.
The main task of the filters in the system is to reduce the solid and aqueous contamination in the fluid.
Fluid filters therefore contribute towards ensuring that modern systems which are exposed to large amounts of aggressive contamination (for instance in the production of cement) can be operated both reliably and economically.

The filter's contribution effectively illustrates how the contaminated fluid can influence the components' function, operating lifetime as well as the maintenance and repair intervals.

The contamination profile in the fluid is represented in oil cleanliness classes. The use of filter elements with a highly effective particle separation is absolutely necessary in order to realize the specified oil cleanliness classes of the high quality components.

The filters used in the system can only then optimally fulfill their tasks if the filters are used in the largest-possible flow rate. Moreover, the contamination intake of the filter element must be at least as large as the contamination penetration during the specified maintenance interval as well as the produced contamination.

The market situation in many system application areas causes maintenance work to be reduced to a minimum. At the same time, the reliability and the economic viability of the systems should not be adversely affected – in contrast they should be increased.

The introduction of a preventive maintenance effectively offers a solution for the difficult market demands.

In order to make this possible and so that any pending component damage is recognized early on, the implementation of **Condition Monitoring** is required.

Notes:

2 Filtration of lubricating oils and hydraulic fluids

The filtration of fluids is mainly a mechanical separation procedure with the aim of separating a suspension into the components "solid matter" (contamination) and "fluids".
In addition to the mechanical separation procedure, only during the regeneration of used and degraded fluids does a chemical neutralization of the acids produced in the degradation process take place. Ion exchanger resins are mainly used as a filter material in these applications.
The solid matter for the mechanical separation procedure may be solid or gelatinous.
The reduction of the solid matter is carried out in the filter elements which are installed in the appropriate housings.

The layering and the structure of the filter materials used in the filter element are responsible for the cleanliness of the fluid.

The following general basic filter principle applies:

- In order to separate particles and fluids, a differential pressure between the filter housing input and output is required
- The differential pressure is dependent on the pore structure of the filter material and the structure of the filter layers
- During the filtering procedure, the filter layers are compressed and the pore volume is reduced: as a consequence of this, the differential pressure and the filter quality increase.
- Dissolved compounds cannot be separated

The safe and reliable operation of stationary equipment, such as transfer lines, machining centers, presses and paper machinery, or heavy industrial and mobile equipment, such as excavators, wheel loaders and bulldozers, is possible only through the use of carefully filtered fluids which are adapted to the respective application. Without these filtered fluids, systems and machines would not function as the friction between the friction partners is high and would lead to rapid destruction of the respective components. For this reason, the condition, characteristics and care of the fluids play an important role in fulfilling the expected lifetime and the degree of effectiveness of the components and the entire system.

The differentiation between lubricating and hydraulic systems is derived from the main tasks allocated to the fluids.

The main tasks, shown in Fig. 1, are mainly:

- Transfer of pressure (energy transfer)
- Component lubrication to reduce friction and wear
- Cooling of components such as for example valves, pumps and bearings

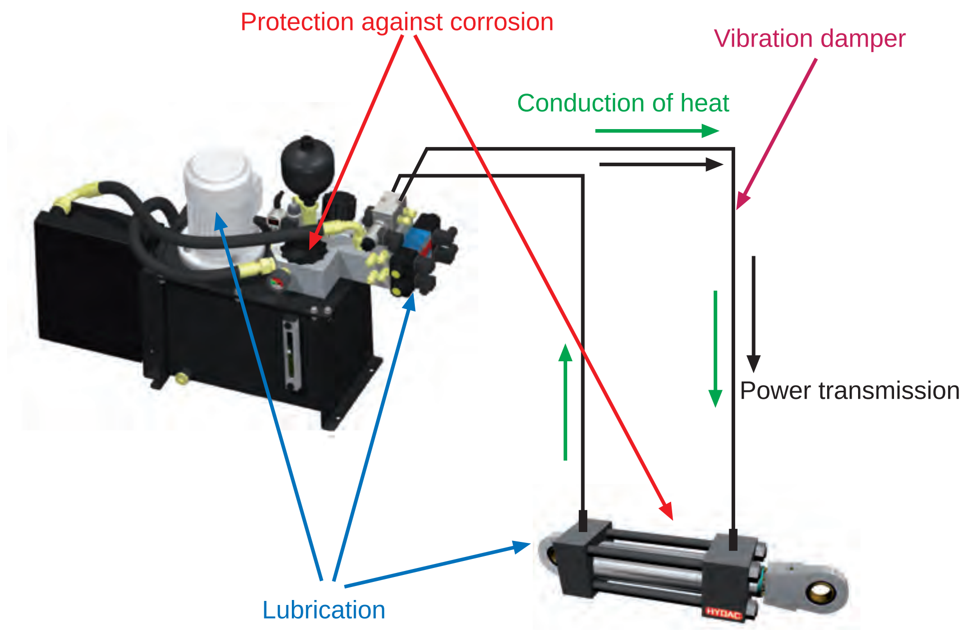

Fig. 1: Tasks of the lubricant in the systems

If one of these functions is impaired, the system is unable to carry out its tasks. The resulting downtimes for a large production plant may result in hourly losses of several thousand Euros.
The fluid must build up a lubricating film for the separation of precision parts. Ideally, this film is strong enough to completely fill the clearance between movable parts. This leads to low wear values. If the wear rate can be kept low enough, the components will reach their target lifetime of up to several million load cycles.
The actual thickness of a lubricating film is dependent on the viscosity of the fluid, the load and the relative working speed of the two surfaces contacting each other. Many components are placed under such strain that they compress the lubrication film down to a very thin film of less than 1 µm in thickness. If the strain becomes too intense, the film will become perforated by the surface roughness of the two movable parts resulting in possible friction damage and mini-welds.

On hydraulic pumps, the main task for the fluid is to transfer pressure. At the same time, it has the task of providing the pressure generated by the pump to every point in the system.

On lubrication systems, the main task of the fluids is to reduce the friction on the components, such as the shaft bearings, pumps (cylinder surfaces) and slide tracks. It is therefore necessary that the fluid forms a sufficient lubricating film thickness that prevents contact between the sliding surfaces.

The use of filters with effective particle separation in the microparticle range is absolutely necessary in order to guarantee the operating function of the components and the entire system. Apart from this, the filter ensures that the wear on the components is minimized and that long component lifetimes and long maintenance intervals can be realized.

Filters therefore play an important role in ensuring that systems operate:

- reliably
- with high and long availability
- with low maintenance and costs and
- economically

Thereby modern systems place extreme demands on the hydraulics and lubrication systems used, and therefore also on the filters.

The key demands are:

- Restricted space conditions or installation spaces
- Fulfillment of high environmental regulation demands
- Major fluctuations in temperature
- Low consumption of fuels
- Rough environmental conditions such as humidity, dust, contamination and chemical substances from the ambient air
- Ease of use
- Easy service and quick condition diagnoses
- Little or no leakage

Damage caused by contamination:

- Wear on nozzles
- Wear on components
- Generation of rust and other oxidations
- Generation of chemical compounds
- Degradation of additives

3 List of standards related to filtration

Standards for the removal, inspection and evaluation of oil samples

No.	Edition	Title
ISO 3722	1976	Fluid technology: Sample vessel for fluids; suitability and checks on cleaning procedures *Identical with E DIN ISO 3722-1988*
ISO 3938	1986	Hydraulic fluids; Method for presentation of the measured values
ISO 4021	1992	Hydraulic fluids: Removal of samples for the determination of contamination taken from a system in operation
ISO 4402	1977	Hydraulic fluids: Procedure for the calibration of automatic counting devices for suspended particles using AC-fine test dust
ISO 4406	1999	Key for the marking of the level of solid contamination in hydraulic fluids *Identical with CETOP RP 70 H-1974*
ISO 5884	1987	Aerospace: fluid systems and components; procedures for sampling and determination of the solid contamination in hydraulic fluids
CETOP RP 94 H	1978	Determination of solid particles in hydraulic fluids using an automatic particle counting device which works according to the light interruption system
CETOP RP 95 H	1979	Recommended method for sampling from hydraulic fluids using a bottle for particle counting
CETOP RP 118 H	1988	Directives for checking contamination in operating fluids in hydraulic systems
CETOP RP 120 H	1990	Calibration procedure for automatic particle counters acc. the light darkening principle using latex balls with uniform measurements

Construction standards for hydraulic filters

No.	Edition	German title
ISO 7744	1986	List of the requirements placed on filters in hydraulic systems *Identical with CETOP RP 92 H-1978*
DIN 24550 Part 1	1988	Fluid technology; hydraulic filters; terms, nominal pressures, nominal sizes, connection dimensions
E DIN 24550 Part 2	1990	Fluid technology; hydraulic filters; assessment criteria, performance data
E DIN 24550 Part 3	1990	Fluid technology; hydraulic filters; filter elements for line filters; cover dimensions
E DIN 24550 Part 4	1990	Fluid technology; hydraulic filters; filter elements for mounted return filters; cover dimensions
E DIN 24550 Part 5	1990	Fluid technology; hydraulic filters; filter elements for mounted return filters; cover dimensions
DIN 24557 Part 2	1990	Fluid technology, breather filter; connection dimensions
CETOP RF 98 H	1979	Directives of the specification, selection and application of breather filters for hydraulic vessels

Standards for filter element tests

No.	Edition	German title
ISO 2941	1974	Fluid technology; hydraulics; filter elements; collapse and burst pressure tests *Identical with DIN ISO 2941-1983*
ISO 2942	1988	Fluid technology; hydraulics; filter elements; verification of flawless production quality *Identical with DIN ISO 2942-1988*
ISO 2943	1974	Fluid technology; Hydraulics; filter elements; Verification of compatibility with the operating fluid *Identical with DIN ISO 2943-1990*
ISO 3723	1976	Fluid technology; Hydraulics; filter elements; Procedure for testing the end disk load *Identical with DIN ISO 3723-1987*
ISO 3724	1976	Fluid technology; Hydraulics; filter elements; Verification of the flow fatigue properties *Identical with DIN ISO 3724-1990*
ISO 3968	1981	Fluid technology; hydraulics; filter elements; Determination of the flow resistance dependent on the flow rate
ISO 11170	2003	Fluid technology; hydraulics; filter elements; series of tests for the inspection of the performance characteristics
ISO 16889	2nd standard	Fluid technology; hydraulics; filter elements; multi-pass test method for evaluation of the filter performance
E DIN 65385	1988	Aerospace; fluid technology; hydraulics; filter elements; test verifications
CETOP RF 109 H	1983	Fluid technology; hydraulics; filter elements; integrity test of a filter element at a low temperature

Notes:

4 Future aspects

In the future, systems must fulfill the following basic requirements and legal regulations:

- Stricter environmental regulations
- Higher demands on components with relation to the construction space, reliability, shaft concentricity, form and positional tolerances
- Increased demands on the production tolerances for ball and roller bearings
- Drives which are subjected to severe strain, such as those used in wind power plants and mills, must have longer and lower-maintenance availabilities or lifetimes
- Machine directive 2006/42/EC – Explosion protection

This means that fluids with

- Heavy metal-free additive packages
- High-quality base oils in category II
- Saturated ester and polyalphaolefins (PAO oils)

From the filter manufacturer’s point of view, this means that:

- The electrical conductibility of the fluids is low.
- The fluid transports more particles (good contaminant release capabilities etc.).
- Oils may no longer be mixed - the resulting oil reaction products block the filter mat.

For this reason, modern filter housings and filter elements especially designed for these future requirements increasingly have to fulfill the following demands:

- Good electrical conductibility of the components used in the filter element
- High particle separation, above all in the finest particle range 4 $\mu m_{(c)}$ and 6 $\mu m_{(c)}$
- High contamination absorption as the range of particles increases in the ultra-fine particle range and, in addition, the demands from system operators for longer, cost-reducing maintenance intervals have increased
- Filter housings and elements are equipped with RFID sensors (= Radio-Frequency Identification Sensors) so that the filters can be monitored using far field systems

Due to the increasing cost pressures, as a result, the quantity and quality of the maintenance personnel is negatively affected. In order to ensure that the system meets the increased demands while remaining economically viable, it is necessary to introduce a preventive maintenance that effectively and continually monitors online the critical system parameters.

In modern machine procurement systems, the holistic costing, calculated across the planned lifetime of the machine, will represent the most important decision criterion.

For this reason, machine and filter manufacturers must be capable of defining any spare parts and maintenance costs required over the system or machine lifetime as accurately as possible. In order to make this possible, comprehensive field tests or field experience must have been carried out by the machine and filter manufacturers.

Notes:

II Contamination

1 Typical damage through contamination

Contamination has a negative influence on the function of lubricating and hydraulic fluids, for example, on the heat and energy transfer, which may even lead to machine downtimes. In the following risk analysis, damage to the components used is diagnosed in 75% of system failures – caused through contamination of the operating medium (representations in Figs. 1 to 5).

Fig. 1: Damage of sealing surfaces

Figs. 2+3: Damage to a gear rim

Fig. 4: Melted white material caused by solid particle contamination and increases in temperature

Fig. 5: Damage to the components of a variable displacement pump

The previous figures illustrating the damage patterns provide a rough overview of the costs incurred due to contamination, caused by:

- Production stops (downtimes)
- Spare part costs
- More frequent fluid changes
- Expensive disposal
- Increased general maintenance costs
- Increased number of rejects

The functionality of bearings, gearwheels and other hydraulic components is based on a thin, strong lubricating film positioned between 2 surfaces. The surfaces slide past each other on this lubricating film without contacting each other.

2 Sources of contamination

In order to prevent system damage due to contamination, it is important to find its cause.

The main sources of contamination are:

- **Assembly protection (Fig. 6)**
  During the various production procedures for components various types of contaminants can arise such as chippings, molding sand, core residues, cleaning cloth fibers, weld beads and scale etc. These mainly coarse contamination types must be removed before commissioning the system through washing out or rinsing the entire system (see also component cleanliness acc. ISO 16232). The results are often unsatisfactory, as the particles are not released until temperatures change or the fluid flow rate increases. In addition the basic contamination of supplied fresh oil also plays a role. The contamination of the supplied fresh oil lies verifiably between 30,000 and 50,000 particles larger than 5 µm per 100 ml (ISO 21/19/16) and is far too high for the operation of modern systems with their usually sensitive controls. For this reason, the system should always be filled and refilled with lubricating and hydraulic mediums using a filter (Fig. 7).

Fig. 6: Embedded machining chip

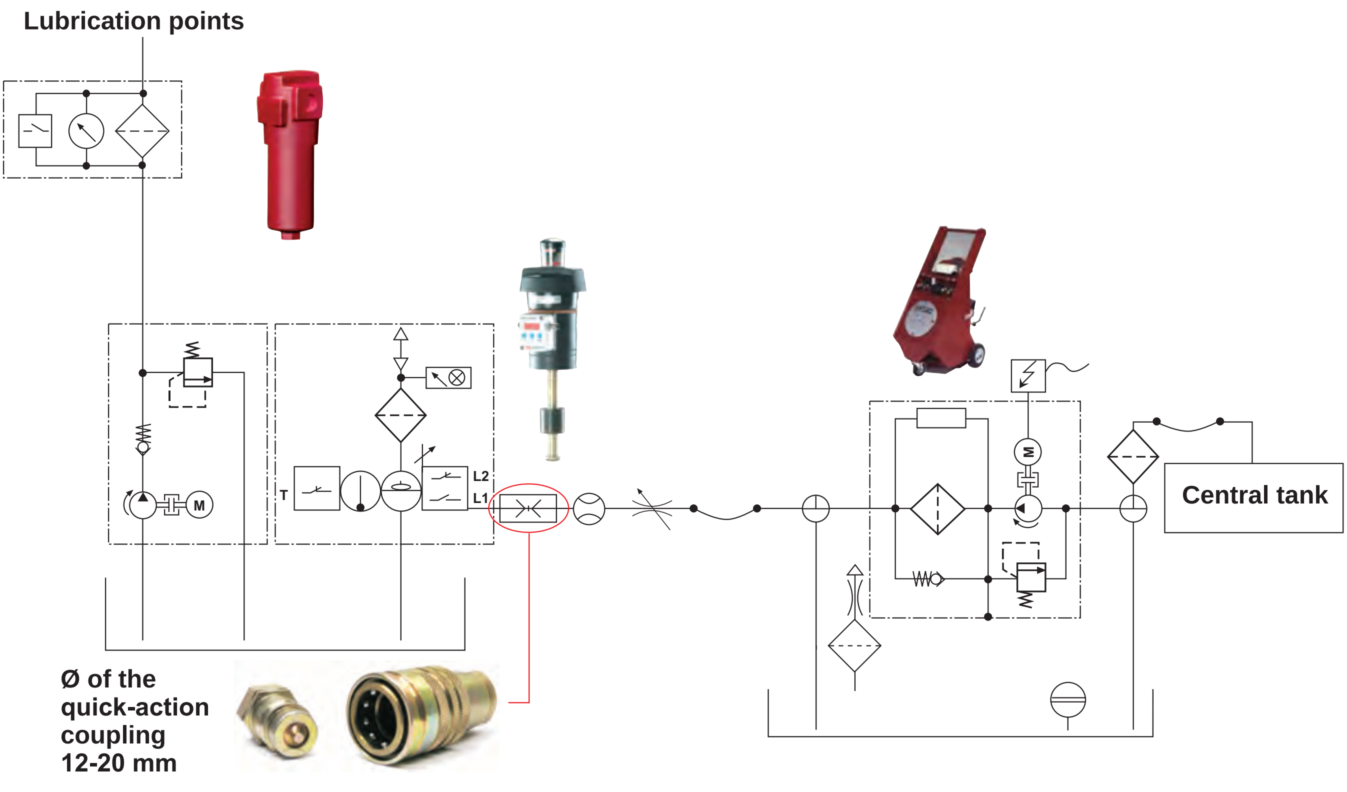

Fig. 7: Filter system for filling and refilling lubrication systems

- **Operating contamination:**
  Abraded particles from the components are transported through the system with the fluid and cause wear accordingly. Chemical by-products, which can for example be generated as the fluid degrades, cause similar reactions on the surfaces which lead to further contamination.
- **Dirt from the surrounding environment:**
  Fine contamination is carried into the system during operation from the surrounding environment via the piston rod or movable seals. Furthermore, microscopic dust particles can access the vessels via the tank ventilation and cause further contamination in the system.

Notes:

3 Types of contamination

Fig. 8 shows the classification of contamination in gaseous, liquid and solid forms as well as its effects on the system.

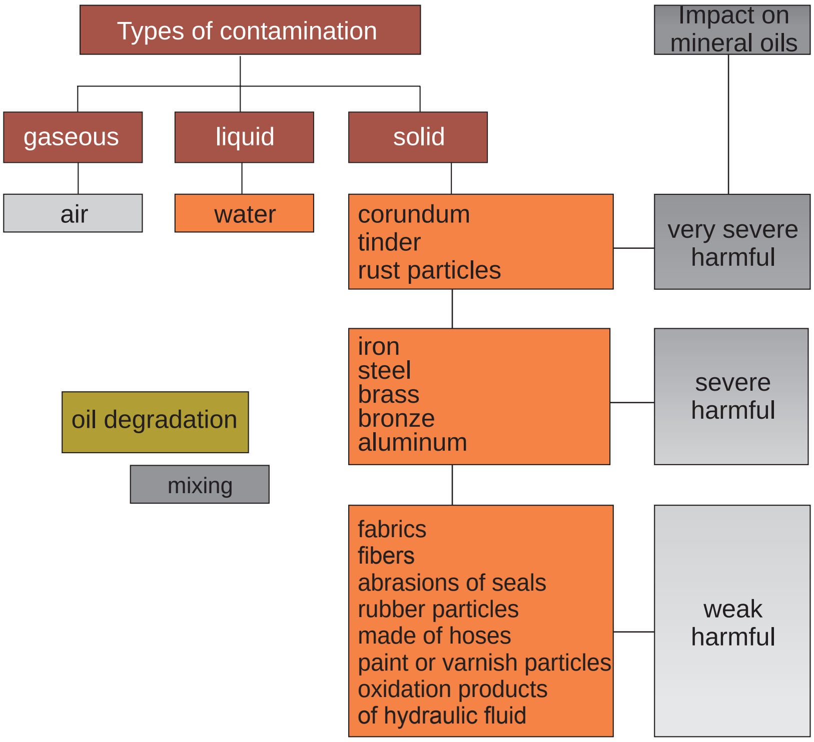

Fig. 8: Types of contamination

3.1 Contamination through air

Lubricating and hydraulic fluids can only bind a certain amount of air (approx. 9%). If more air gets into a fluid, air bubbles are formed and the system performance is affected. Due to air being 20,000 times more compressible than fluid, the volume structure of the fluid is altered by the air intake. The pump performance is reduced as the air also has to be compressed. Moreover, the entire system runs in a "spongy" manner. The lubricating film bearing capability on gears is reduced.

Through compressing the air bubbles, a "micro-diesel effect" typically occurs, and the fluid combusts or oxidizes (see Fig. 9). These oxidation processes boost the formation of particles or sludge within the fluid. For this reason, the oxidation substances must be quickly removed.

Possible causes:

- Leakage within the system (mostly in suction and return lines)
- Air intake through the pumps or the gears
- Turbulences inside container
- Faulty construction of devices (e.g. return lines, which terminate above the fluid level in the tank)
- Chemical changes to the fluid (degradation products etc.)
- Turbulences in the pipelines and components (low pressure and temperature suddenly produce changes in air release capabilities)

Fig. 9: Self-ignition of an air bubble through the diesel effect

Damage patterns:

- Loss of transferable energy
- Diminished pump production and premature pump failure
- High levels of noise (loud noises from the pump)
- Reduced lubrication capabilities
- Increased operating temperature
- Fluid in tank foams up
- Chemical reaction (fluid degradation)
- Cavitations on valve and pump control elements
- Localized overheating of fluid (micro-diesel effect)
- Unstable control behavior
- Reduction of the dynamic lubricating filter thickness

Preventive measures:

- Careful venting of the system
- Position the suction pump under the oil level in the tank
- Proper design of the suction and return lines, as well as the tank configuration.
- The fluid should be in the tank or the gear housing for long periods of time to ensure degasification
- Increase in the “degasification speed” through design measures on the tank, for example large, sloping return duct

3.2 Contamination through water

Solid matter and water are the most dangerous contaminants in a fluid system. Mineral oils as well as synthetic oils have a temperature-dependent water saturation point. Above this point, free water (emulsified) occurs (see Fig. 10).

The typical saturation point on lubricating oil is:

400 ppm = 0.04%

The additives present in the fluids cannot take effect if free water is present. As a result, oxides, acidic sludges and resins are formed. Above all, the free water may freeze inside systems which are operated below freezing point. The resulting ice crystals can compromise the function of the overall system and lead to down-time.

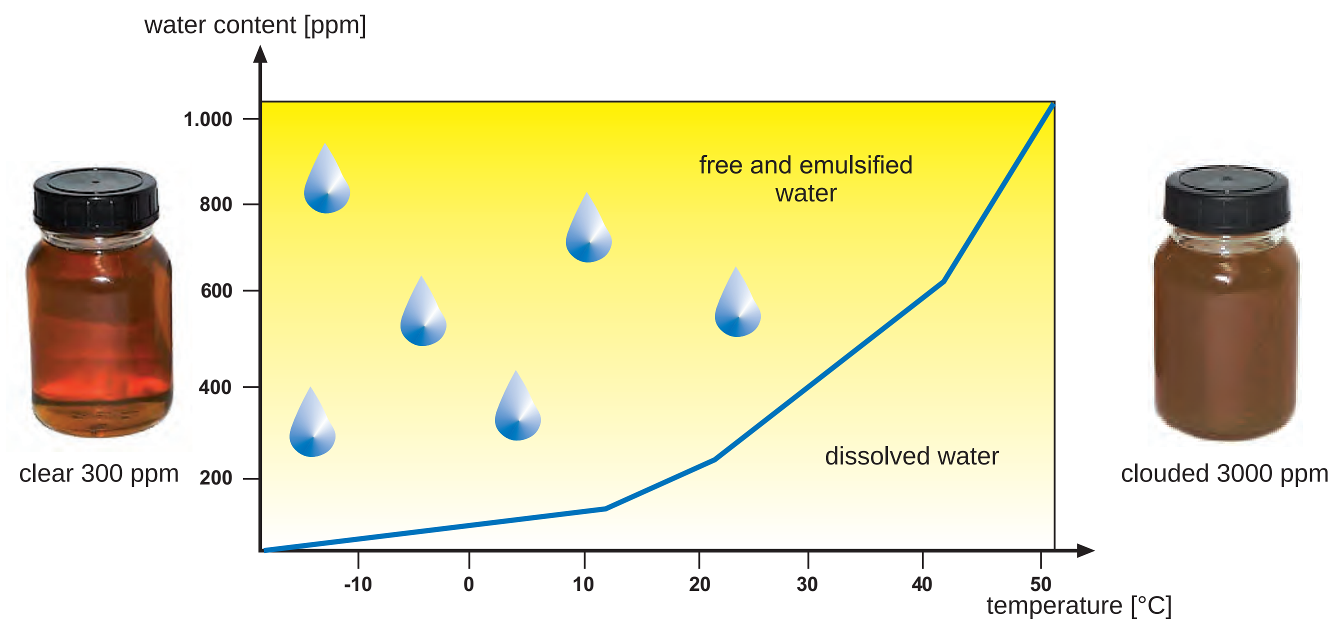

Fig. 10: Saturation limit for water in a lubricating oil

Possible causes:

- worn out piston rod seals
- open tank inlets
- formation of condensation water due to extreme temperature fluctuations
- leakage in heat exchanger
- incorrect machine cleaning procedures; i.e. steam cleaning, which can press the steam via the breather filter into the tank

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