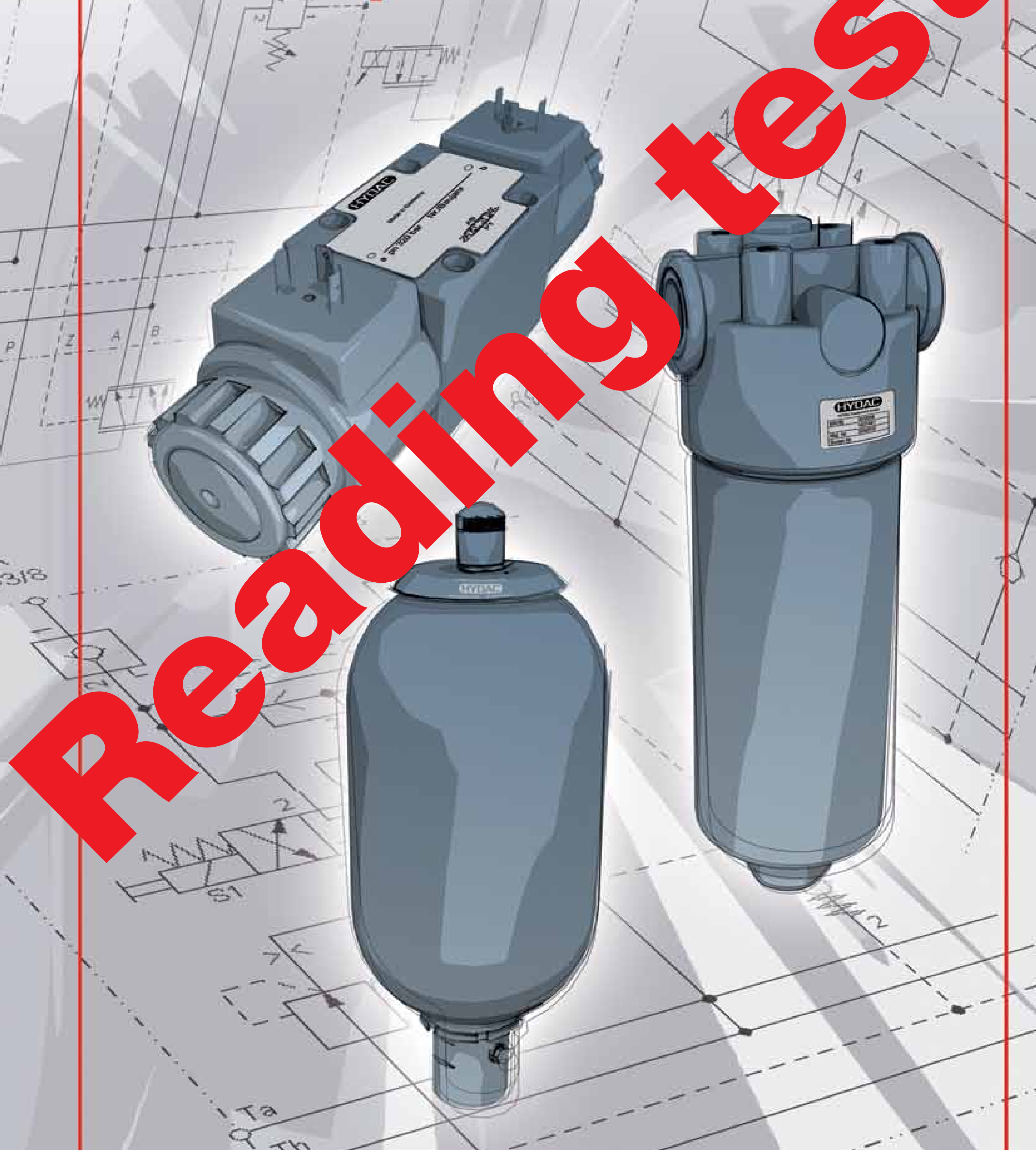
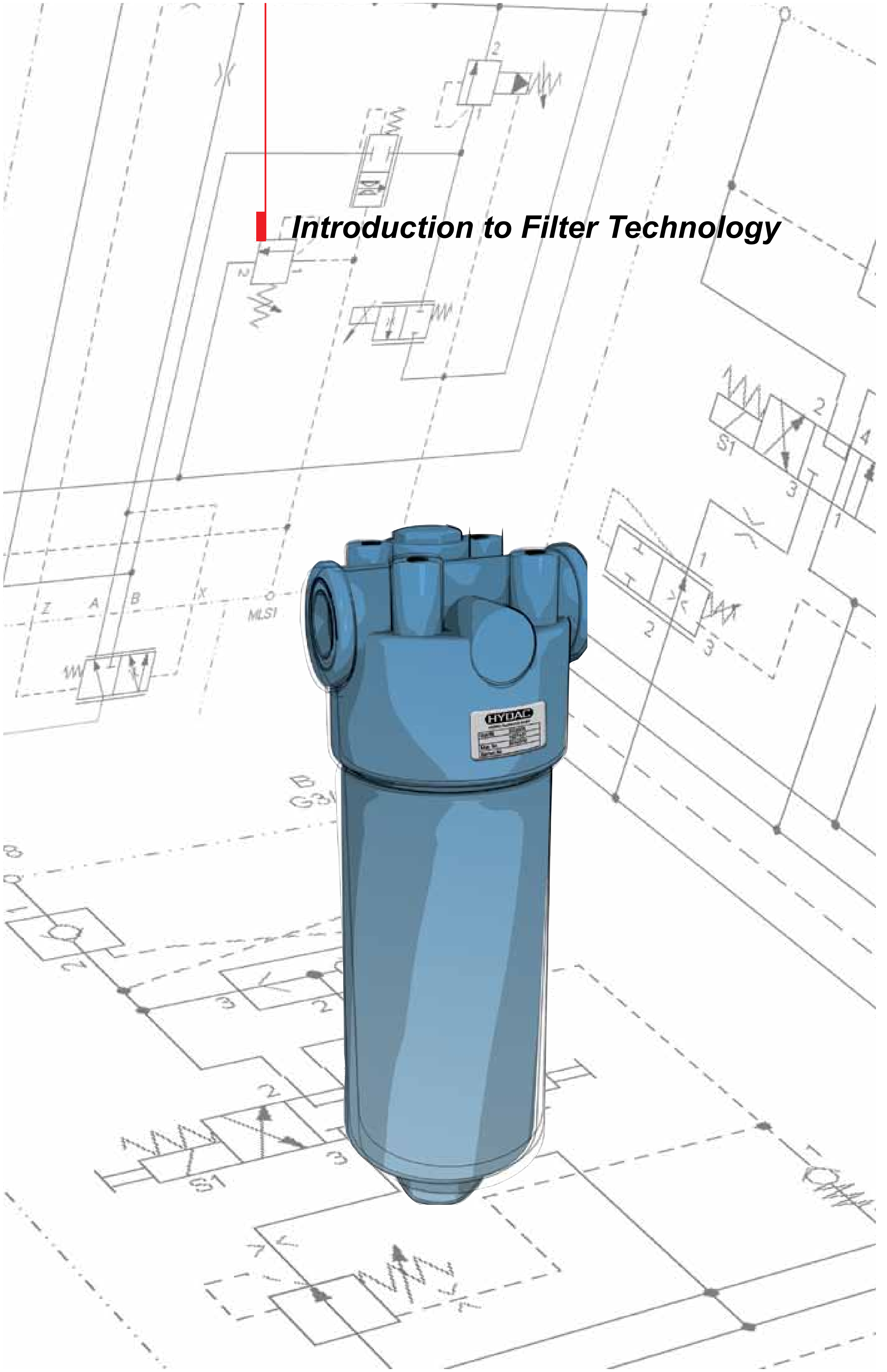
HYDAC TRAINING CENTER

Hydraulics –
Basics and Compone



Introduction to Filter Technology



IV Introduction to Filter Technology

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1 Introduction

70 % of all failures in lubrication and hydraulic systems are fluid related. This means that fluids play an important role in hydraulic units. The cleaner the oil and the better it is protected against external influences (contamination, solid, fluid, gaseous and mixtures) the more efficiently and economically hydraulic units can be operated.

Why is filtration so important?

Choosing the optimal solution for filtration is an essential step to avoid damage due to contamination, to increase the running time of the unit and consequently its productivity.

The development in hydraulics in recent years is essentially concerned with faster and more precise switching of valves. Pumps, valves and actuators feature less and less oil leakage despite the fact that pressures increase in hydraulic systems. This increase in performance can only be achieved by minimizing the valve clearance in hydraulic components. Consequently higher requirements and standards are made with regard to cleanliness in mounting the hydraulic components and handling the operating fluids.

This is particularly true for all proportional and servo valves. The purity of all fluids has to be extremely high. Therefore all manufacturers of hydraulic components have to specify with what degree of contamination the components can function permanently.

If you consider the direct impact of fluid characteristics on the economic feasibility and the efficiency of the hydraulic and lubrication system, the necessary actions are obvious: Cooling, continuous online surveillance and a comprehensive filtration concept, all of which guarantee the efficiency and operational reliability of the entire system. This means that cooling, filtration and oil diagnosis play a decisive role in reducing operating costs.

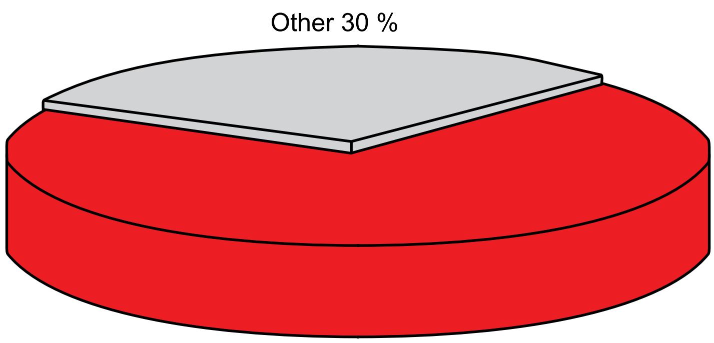

Fig. Reasons for failures in hydraulic and lubrication units

Notes:

2 Contamination Types

The figure below shows a classification of gaseous, fluid and solid types of contamination and their impact on the hydraulic system

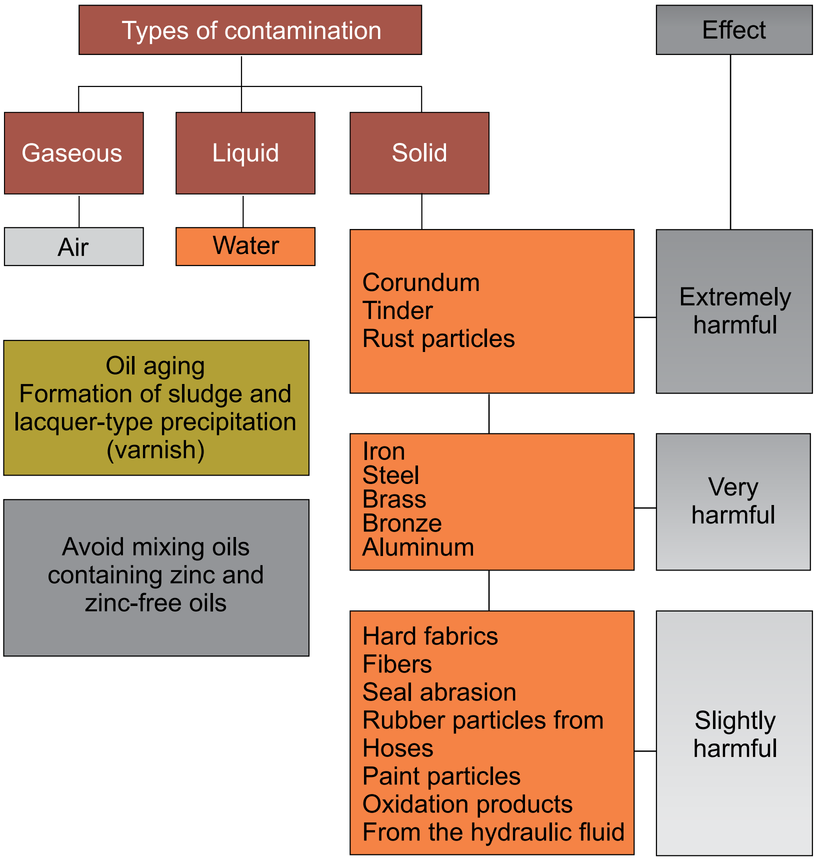

Fig. Overview: Classification of contamination

2.1 Contamination caused by air

Hydraulic and lubrication fluids can only bind a certain quantity of air (approx. 9 %). This "natural" percentage of air contamination has very little impact on the operation of lubrication and hydraulic units. However, if the oil has already aged or if different oils are mixed, the sojourn time in the tank is not long enough to separate the air from the oil. If more air gets into the fluid, the efficiency of the system is compromised. Since you can compress air 20,000 times more than fluids, the volume structure of the fluid is thus changed. The useful work performed by the pump is reduced because the air must be compressed as well as the operating fluid. By compressing the air bubbles, quite frequently the so-called "Micro Diesel Effect" is created. This happens when the pressure is increased rapidly, as it is possible in a pump, Consequently this results in adiabatic compression of the fluid, which in turn results in an increase of temperature.Once the ignition temperature of the fluid has been reached, flames are formed and the fluid burns locally in the area of the air bubble. Since the air bubbles do not contain sufficient oxygen, the burning process is not completed. Soot is generated, which blackens the fluid and forms sludge within the fluid. Oxidation processes boost the formation of particles or sludge within the fluid, which reduces filter lifetimes. The oil (fluid) smells burnt. Therefore oxidation debris has to be removed very quickly.

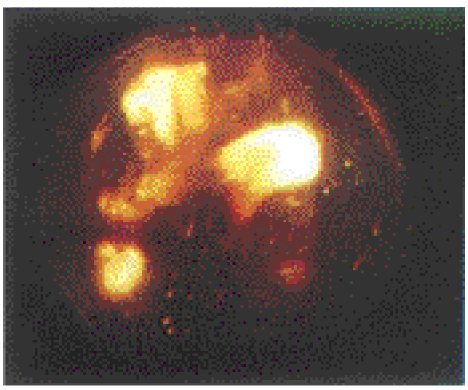

Fig. Self ignition of an air bubble due to the micro-diesel effect

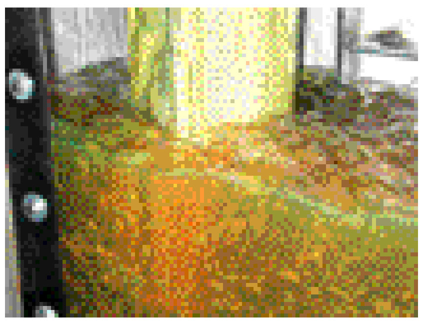

Fig. Hydraulic fluid contamination with air due to incomplete and faulty flooding of filter element in the tank

Causes:

- Leakage within the system (mostly in suction and return lines)
- Air suction caused by pumps
- Turbulences inside container
- Faulty construction of components (i.e. return lines, which terminate above the fluid level in the tank)
- Pump effect of cog wheels in gears
- Water in oil
- Used additives
- Mixing of different types of oils
- Mixing with substances containing silicone
- Incorrect calculation of air release capacity and sojourn time of the oil inside the tank
- Return above the fluid level
- Determination of tank size

Consequences:

- Cavitation
- Foaming
- Shortened filter life
- Increased fluid temperature

Fig. Fluid contaminated with air

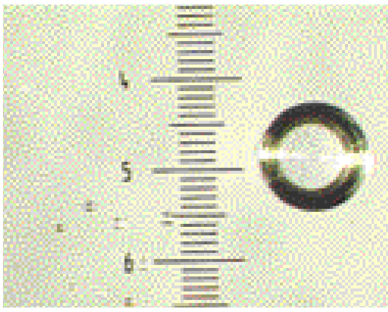

Fig. Oil analysis

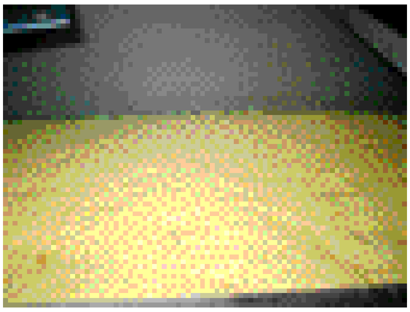

Fig. Formation of foam in hydraulic tank (foaming fluid in tank)

Damage patterns:

- Loss of transferable energy
- Diminished pump production and premature pump failure
- Loud noises from the pump
- Reduced lubrication capabilities
- Increased operating temperature
- Foaming fluids in tank
- Chemical reactions
- "Soft" hydraulics (compressibility of operating fluid is increased), dangerous post tracking movements
- Shorter oil and component change intervals
- Clogged filter elements
- Permanent filtration in filter housing
- Formation of varnish

Preventive measures:

- Careful venting of the system
- Fitting the suction pump below oil level in the tank
- Flow-favorable and correct construction of suction and return lines, as well as tank designs
- Sufficiently long fluid resting times in the tank (to ensure tank degassing)
- Increasing the "degassing rate" through design measures in the tank (e.g. large, tilted run-off plates in the degassing unit installed in the hydraulic circulation system)
- Proper installation of hydraulic lines (avoid u-bend formations)
- Avoid mixing different types of oil

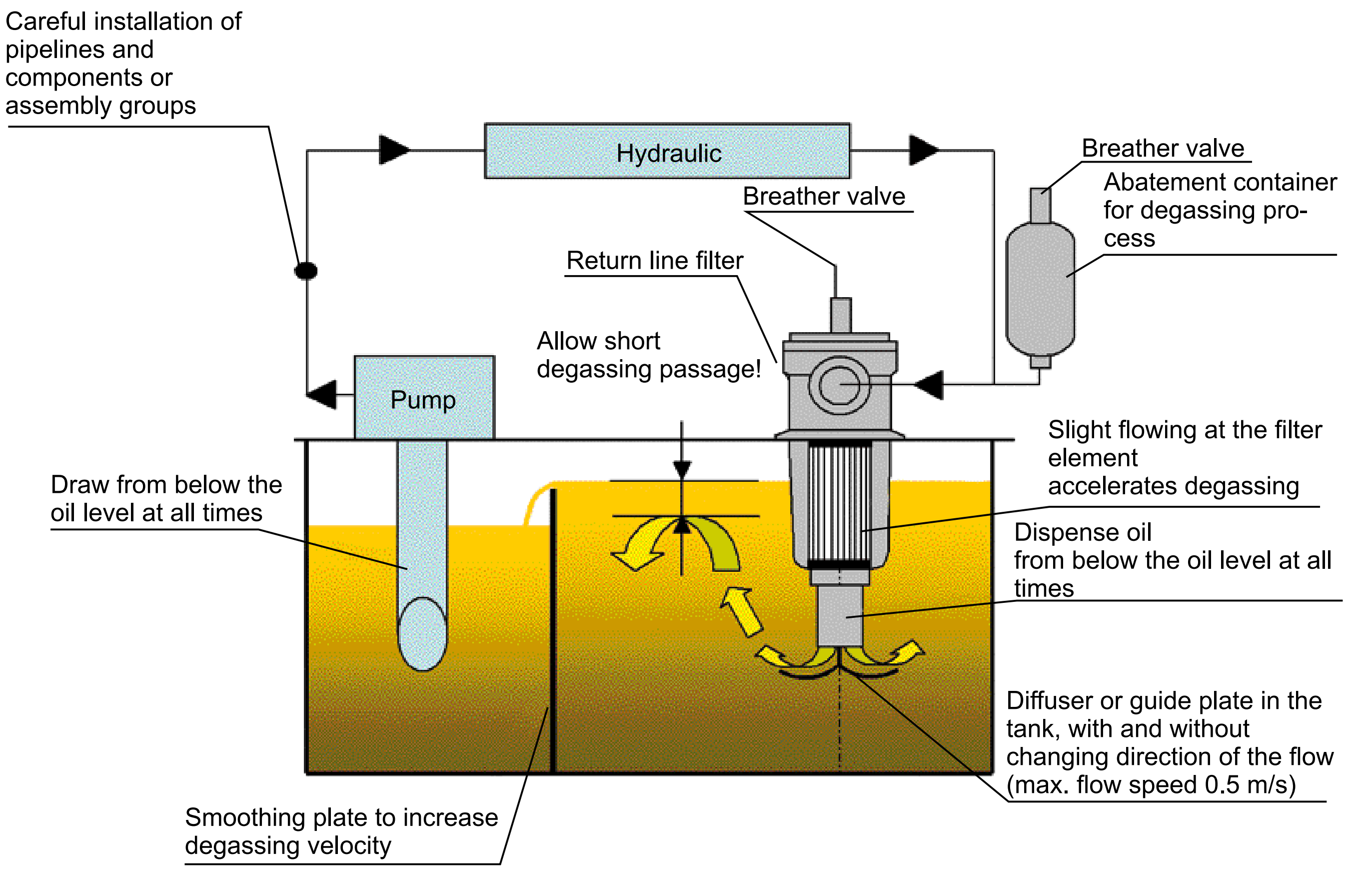

Fig. Degassing of lubricant oils and hydraulic fluids

Fig. "Plastic tank solution"

Filtration techniques:

There are very few filtration techniques to deal with contamination through air.

These include:

- Vacuum evaporation
- Coalescing elements in the bypass flow

The oil aging products emerging due to the trapped air can be removed by an effective offline flow filtration unit (Type OLF, IXU, FAM).

2.2 Contamination caused by water

Solid particles and water are the most dangerous types of contamination in fluid systems. Both mineral oils and synthetic oils have a temperature related degree of water saturation. If this point is exceeded, free (emulsified) water develops. Typical points of saturation are: 300 ppm (0.03 %) for hydraulic oils, 400 ppm (0.04 %) for lubricating oil and 1000 ppm (0.1 %) for faster biodegradable fluids (synthetic ester).

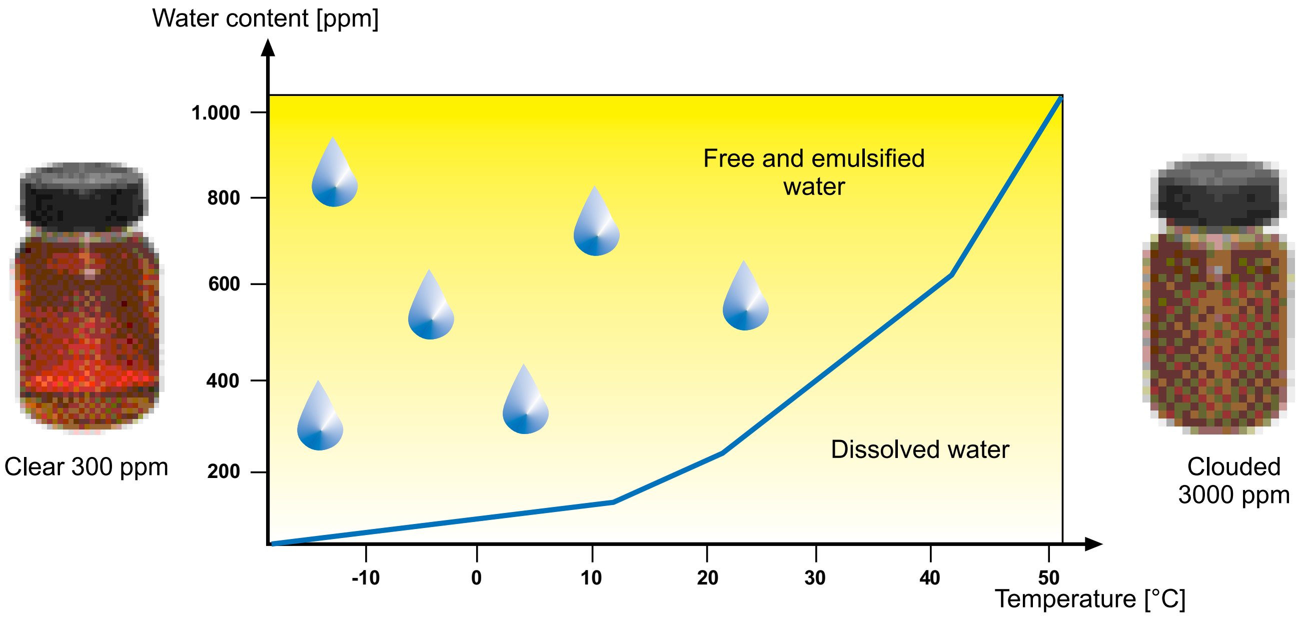

Fig. Saturation limit for water in hydraulic fluid

Typical water concentration ÷ 100 ppm = 0.01 %:

	Average water content	In percent up to saturation at temperature
Mineral oil based hydraulic fluids	100 ppm	15 - 30 % at 40 °C
Lubricating oil based on mineral oil	100 - 200 ppm	20 - 35 % at 40 °C
Polyglycol	2000 - 4000 ppm	20 - 35 % at 40 °C
Bio oil (HEES/HETG)	500 - 800 ppm	20 - 35 % at 40 °C

Additives present in the fluids react with the free water. Oxides, acidic sludge and resins form as a consequence. For systems operated below freezing point, there is a risk of the free water freezing. The resulting ice crystals generated can compromise the function the overall system and lead to failure. The water content in hydraulic fluids should not exceed the following amount: 0.12 % (1200 ppm). From a water proportion of 0.06 % (600 ppm) oil conservation measures must be introduced (FAM, Aquamicron© elements).

Causes:

- Worn out piston rod seals
- Open tank inlets
- Formation of condensation water due to extreme temperature fluctuations
- Leakage in heat exchanger
- Improper cleaning of machinery (e.g. the use of steam cleaning, which can force the steam into the tank via the breather filter)

Damage patterns:

- Corrosion of metal parts (inner wall of tank, rust can be found in fluid samples)
- Increased abrasive wear
- Bearing damage
- Breakdown of additives
- Changes in oil viscosity
- Sludge formation
- Formation of varnish

Preventive measures:

Design of hydraulic tank:

Free water is heavier than hydraulic fluids and lubricants and therefore sinks to the floor of the tank. If the tank and tank floor have been designed appropriately, the free water which has gathered at the bottom of the tank can be removed by opening the outlet valve. However, this is only possible if there is no turbulence inside the tank or if the unit has been idle for several days.

2.3 Contamination caused by solid matter

Origin and development of contamination:

- Integrated contamination through installed components (e.g. valves, fluids, cylinders, pumps, tanks, hydraulic motors, hoses, pipes) - Component cleanliness
- Contamination produced during assembly of the system, by opening the system, during system operation and during fluid-related system failure.

Contamination due to external circumstances, like:

- Tank breathing
- Cylinders, seals
- Contamination entering the system during maintenance procedures
- During system setup or system dismantling procedures
- When the system is opened
- When refilling with oil

The following figure shows possible reasons for contamination:

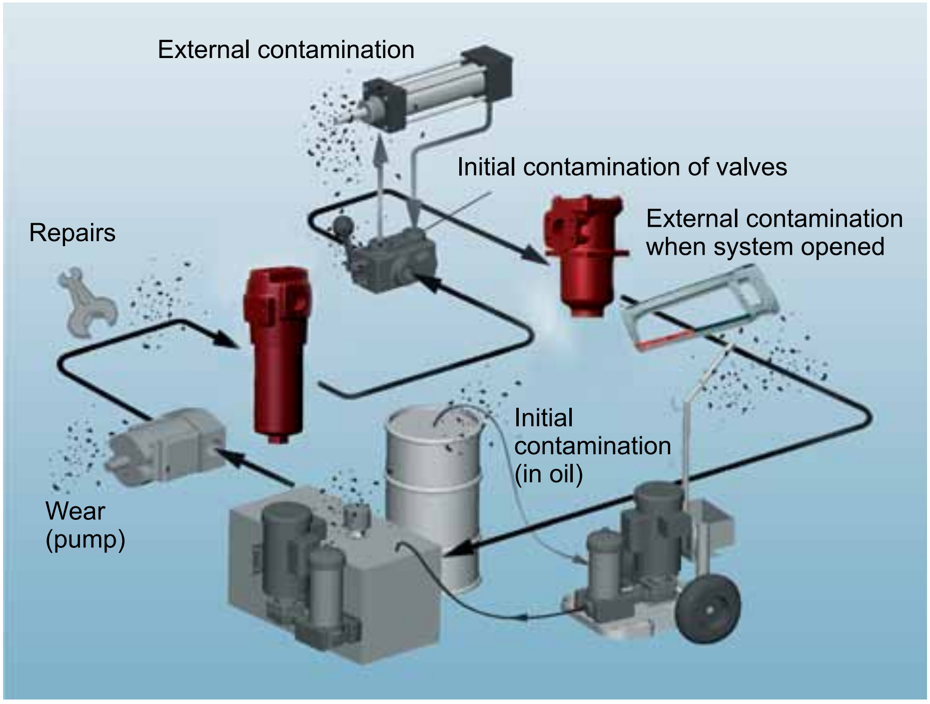

Fig. Origin of contamination

If the most expensive components become damaged due to solid particle contamination of the hydraulic fluids and lubricants, a complete system failure might occur. Increased contamination with solid particles gradually leads to lower degrees of efficiency. The intensity of the component damage depends on the contaminating material, the operating overpressure, the physical features (round or edged) and the size and number of particles. The harder the particles, the more extensive the damage to the components and the higher the operating overpressure, the harder the particles are pushed into the lubricating slots. It must be borne in mind that the majority of these solid particles are smaller than 30 µm and are not detectable with the naked eye. This means an apparently clean fluid can, in fact, be severely contaminated.

Below you will find the typical particles in a comparison of sizes:

Material	Particle size
Grain of salt	100 µm
Human hair	75 µm
Lower limit of visibility	30 µm
Fine flour	25 µm
Red blood cells	8 µm
Bacteria	2 µm

Additionally customers using hydraulic systems demand smaller, lighter and more powerful components, which in turn means that the clearance (lubrication slots) become smaller and smaller as well.

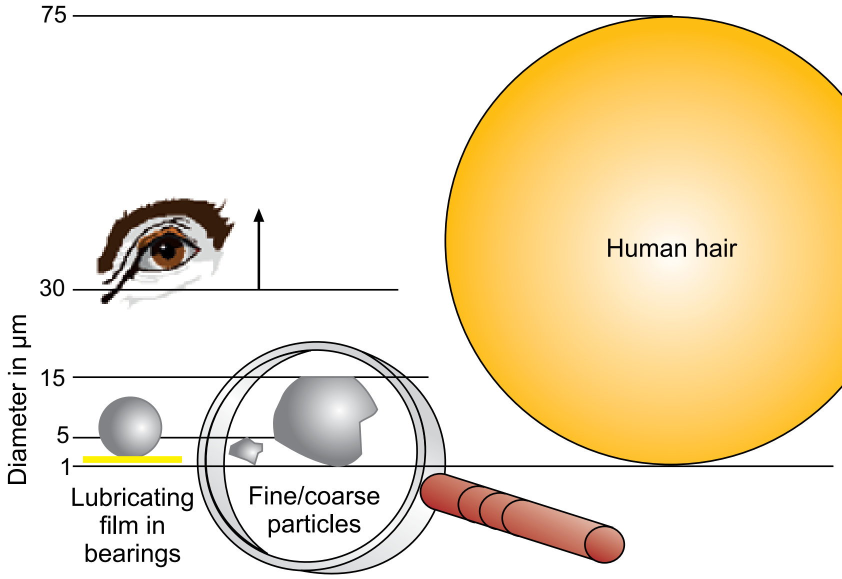

Fig. Particle size

Below you will find typical orifice sizes:

Hydraulic component	Orifice size
Low friction bearing	0.5 µm
Vane pump (vane tip/external ring)	0.5 - 1 µm
Gear pump (gear wheel/side plate)	0.5 - 5 µm
Servo valve (piston/bore hole)	1 - 4 µm
Hydrostatic bearing	1 - 25 µm
Piston pump (piston/cylinder bore hole)	5 - 40 µm
Servo valve (flapper plates)	18 - 63 µm
Hydraulic cylinder (clearance)	50 - 250 µm
Servo valve (nozzle)	130 - 450 µm

Particularly problematic are those dirt particles whose size corresponds exactly to the fitting allowance and who are very sturdy. They scrape along the surface (abrasion) and fairly quickly damage the components. This process produces more and more dirt particles from the component abrasion and from ground down coarser particles. The result is a high concentration of dirt particles inside the unit.

Consequences:

- Increase of leakage
- Jammed pistons
- Changes to the switching time of the valves
- Reduction of flow rate in pumps
- Orifices and nozzles become blocked

Which types of wear and tear are there, and what are their designations?

- **Abrasion:**
  caused by particles between see-sawing surfaces.
- **Erosion:**
  caused by particles and high fluid velocities.
- **Corrosion:**
  due to water (rusty components) or chemicals (aging of fluids).
- **Adhesion:**
  due to friction between metal parts (fluid loss).
- **Cavitation:**
  Components with highly sensitive and delicate surfaces contact each other (lack of fluids).
- **Surface fatigue:**
  surfaces damaged by dirt particles are repeatedly overstrained.

Notes:

3 Classification of Solid Particle Contamination – Purity of Fluid

How clean should a fluid be?

The desired cleanliness of operating fluids is determined according to the design of hydraulic units and their components. The cleaner a fluid, the longer the life-span of the components. The application of highly sensitive and delicate components like proportional and servo valves demand a particularly high cleanliness of fluids. If the requirements of the purity classification are always met, damage to components such as valves, pumps and motors can be avoided. Thus the life-span is extended and operating costs are shortened. There are different measurement techniques to determine the cleanliness of operating fluids which make a classification possible. This chapter introduces you to the different classification systems and you will be given a brief overview concerning these cleanliness classes.

How do you classify?

The classification of solid particle contamination in lubricants and hydraulic fluids (acc. size and count, not acc. material) is conducted according to **ISO 4406/1999**.

On top of that, there are further classification systems, which are still being used in hydraulic unit documentations:

- NAS 1638 (retracted, do not use for new systems)
- DIN ISO 4406/1999
- CETOP RP 70 H
- SAE AS 4059
- SAE 749 D
- MIL STD 1246 A

In order to determine the fluid purity classes the solid matter particles in 100 ml fluid are counted. They are categorized according to size and number and subdivided into particle ranges.

Depending on the method of particle counting, there are 2 or 3 ranges:

Particle counting	Particle sizes		
Automatic particle counter	> 4 $\mu m_{(c)}$	> 6 $\mu m_{(c)}$	> 14 $\mu m_{(c)}$
Microscopic count	–	> 5 µm	> 15 µm

This is done with the help of microscopes or electronic particle counters. Counting with an electronic particle counter is more impartial in comparison to counting with a microscope. From a dirt concentration of about 30 mg/l or when the fluid is very cloudy, the level of contamination can only be determined by weighing the dirt (gravimetric analysis). The individual contaminant particles cannot be classified with this procedure.

The ISO code can be "translated" with the aid of the table into a maximum particle quantity per particle size range. This code is determined for every single size range. The purity class of an oil measured by an electronic particle counter is indicated by a three digit number combination, e.g. 21/18/15; if the particle count has been determined with a microscopic count, it will be indicated by a two-digit number, e.g. 18/15.

Gravimetric effect:

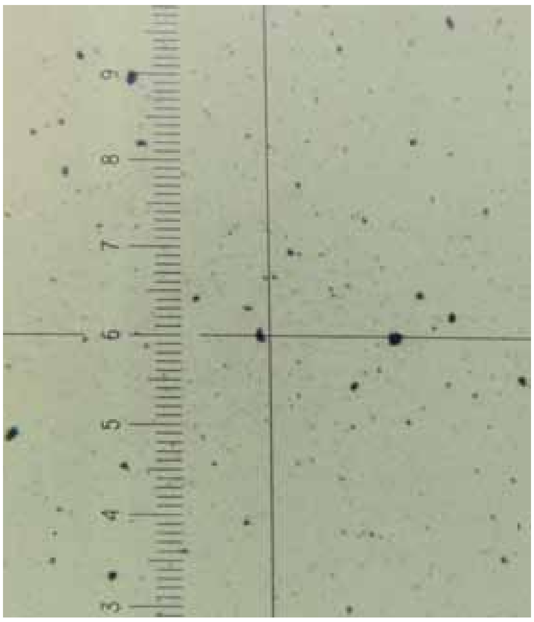

Fig. Typical contamination of class 21/19/16

Fig. Typical contamination of class 17/15/12

3.1 Contamination Classes acc. ISO 4406/99

ISO code (acc. ISO 4406)	Particle count/100 ml	
	from	to
0	0.5	1
1	1	2
2	2	4
3	4	8
4	8	16
5	16	32
6	32	64
7	64	130
8	130	250
9	250	500
10	500	1000
11	1000	2000
12	2000	4000
13	4000	8000
14	8000	16000
15	16000	32000
16	32000	64000
17	64000	130000
18	130000	260000
19	260000	500000
20	500000	1000000
21	1000000	2000000
22	2000000	4000000
23	4000000	8000000
24	8000000	16000000
25	16000000	32000000
26	32000000	64000000
27	64000000	130000000
28	130000000	250000000

Determined with

...Electronic particle counter

21 / 18 / 15

$> 4\ \mu m_{(c)}$ $> 6\ \mu m_{(c)}$ $> 14\ \mu m_{(c)}$

...Microscopic counting

\- / 18 / 15

$> 5\ \mu m$ $> 15\ \mu m$

Accumulators DEF 3.000

Filtration Range DEF 7.000

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Acces...

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