HYDAC FILTERTECHNIK

Filtration of modern zinc-free and ashless hydraulic and lubrication oils

HYDAC Filtertechnik GmbH

When modern, environmentally-friendly hydraulic and lubrication oils are used, or incorrectly handled, there is the risk of electrostatic discharge and an escalation in the formation of oil ageing products, also called varnish. As a result, the components integrated into hydraulic and lubrication oil systems are severely restricted in their function or even damaged. Electrostatic discharges destroy filter elements, damage valves and sensors and can even cause explosions in the hydraulic tank. Valve pistons will stick, shafts become jammed in their bearings and the changing interval for filter elements will be unusually short if there are excessive amounts of ageing products in the operating medium.
To ensure that the whole system operates economically and without risk, it is essential to use filter systems which are capable of absorbing oil ageing products and which can prevent dangerous electrostatic discharges from occurring. Unscheduled and costly oil changes can be avoided by using this system of filters.

1 Introduction

Globalisation of markets compels oil producers worldwide to supply consistently high quality hydraulic and lubrication oils to the manufacturers and operators of systems, such as compressor stations, large transmissions or machines. For group I base oils, where the molecular structure of the crude oil has not been changed, this is not guaranteed. Increasingly, therefore, base oils are used where the molecular structure has been broken down by hydrocracking and then selectively rearranged according to requirement. Refinery capacities of oil producers all over the world are currently geared to this trend (in Asia and the USA, for example, predominantly group II base oils or higher are produced).
To achieve the oil characteristics guaranteed by the oil producers, additives (usually several, as an additive package) must be added to the base oil. Group I base oils contain aromatics most of which are toxic. In addition the additive packages contain zinc which is a heavy metal, and ash is produced on combustion. They therefore no longer comply with the current international environmental standards.

Hydraulic and lubrication oils in group II to IV which are produced with appropriate additive packages, contain no toxins or carcinogens, are free of heavy metals and do not produce residues as a result of combustion.
However, as they do not contain any metal, these oils have low electrical conductivity (see Fig. 1). If this oil flows through the filters in the hydraulic system, an electrostatic charge is generated. This can result in sparking in the system (see Fig. 2), causing explosions in the tank or damage to hydraulic components, such as valves and filters. Furthermore, the discharges can destroy electronic components and they cause oil ageing products to form.

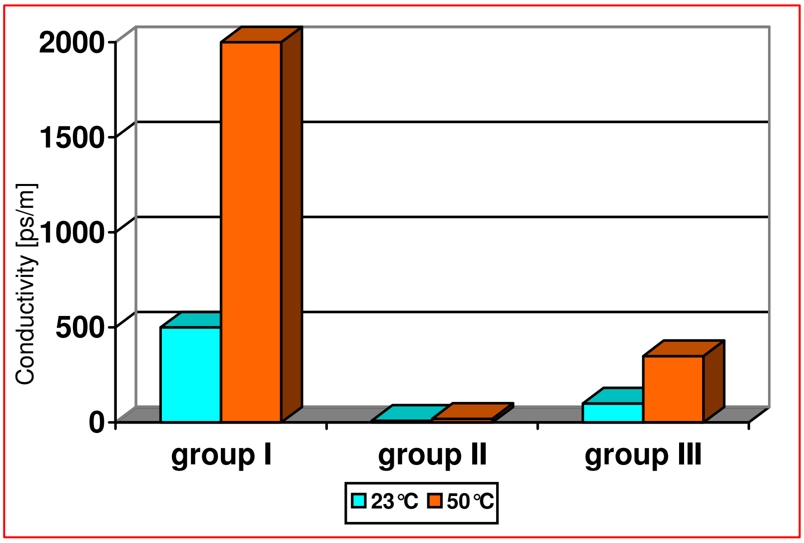

Fig. 1: Examples of conductivity in oils of different groups

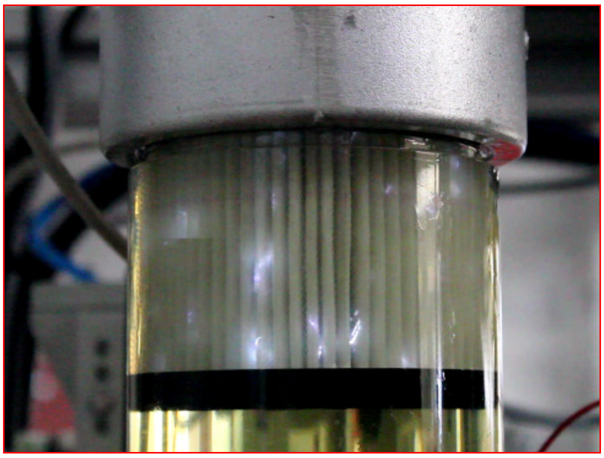

Fig. 2: Electrostatic discharges in the filter element

Filter elements which significantly reduce charge generation play a crucial role in ensuring that hydraulic and lubrication systems can be operated safely, reliably and economically, now and in the future. This article explains how electrostatic charge is generated in the filter element and demonstrates the advantages of the new HYDAC Stat-Free element technology.
When modern zinc-free and ashless oils age, very fine (< 1 µm) solid contamination is formed which does not dissolve in the oil and which is called varnish. This dirt settles on the oily surfaces of the components and has a detrimental effect on the function of the components. The consequences are, amongst other things, seized valve spools, overheated solenoids and extremely short filter element service lives or filter element changing intervals. Filter systems which are equipped with special filter media reduce solid ageing products by means of their large surface area and their capacity to neutralize acidic oil components. This article will present these special filter systems.

2 Electrostatic Discharges

2.1 Formation of charge

If two substances (e.g. filter media and oil) which have different electron work functions are brought together, then at the point of interface, electrons are transferred from the material with low work function to the material with higher work function. In the fluid, ions generate the charge carrier. At the interface with the fluid, there is an electron deficit and in the fluid a diffuse layer forms which has the opposite charge to the filter media. The charge of this layer diminishes with increasing distance from the filter media.
When the fluid is flowing, the charge is carried downstream and creates a difference in potential (= voltage). The faster the fluid is flowing, the higher the potential difference will be. If the voltage generated exceeds a certain limit, there will be a sudden equalization of voltage which is usually in the form of sparking (see Fig. 3). This is conditional, however, on the fluid having a sufficiently low conductivity, otherwise the charges in the diffuse layer can flow back and can be equalized. Since metallic additives are no longer used in modern hydraulic and lubrication oils, this condition is met. [1]

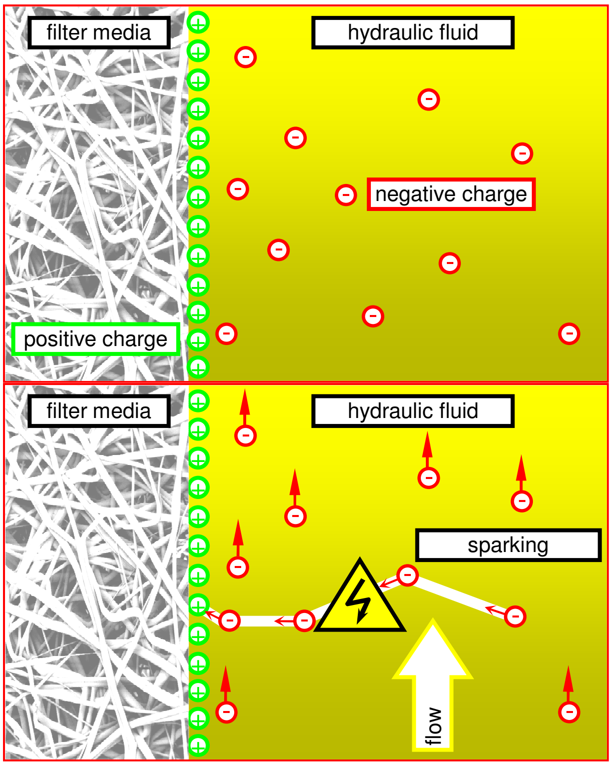

Fig. 3: Charge generation and electrostatic discharge

Electrostatic charge generation is dependent, amongst other things, on temperature, viscosity, flow velocity and the degree of contamination of the fluid (see Fig. 4). [2]

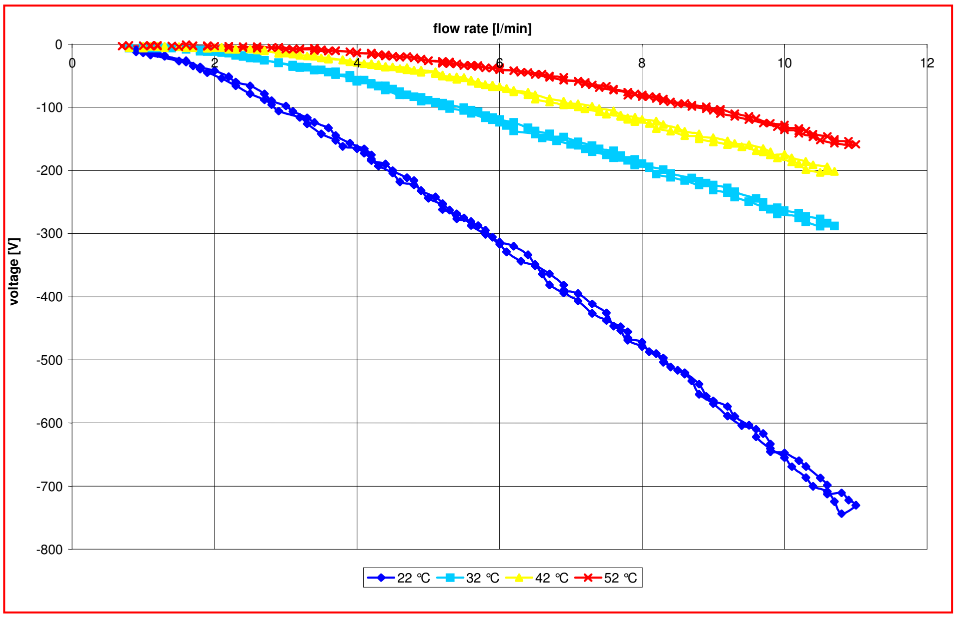

Fig. 4: Voltage in the oil at different temperatures

2.2 Consequences

The consequences of electrostatic discharges can be serious. For example, when the charge is carried further downstream by the oil, uncontrolled discharges can occur in the hydraulic tank. Depending on the oil/air mixture in the tank, dangerous explosions are possible.
In addition, holes are burned in the filter medium as a result of sparking. Fig. 5 shows a hole of about 200 µm in 3µm filter media. The required oil cleanliness is therefore no longer achievable.

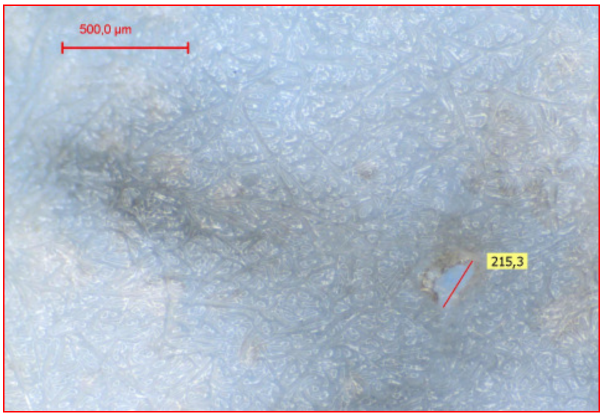

Fig. 5: Hole burned in filter media

Other components in the system, such as coolers and valves, can also be damaged by uncontrolled discharges.
The electrostatic discharges cause electromagnetic waves which disrupt and damage sensitive sensors and electronic components in a hydraulic system.
It is not only hydraulic components but also the hydraulic oil itself which is damaged by discharges. The sparking cracks the molecules of the fluid and free radicals are formed. These radicals polymerize into long chains and this in turn leads to the formation of varnish. In addition, the free radicals accelerate oil ageing.

2.3 Solution

With the help of our specially developed test rig (see Fig. 6) which has been certified by TÜV, HYDAC Filtertechnik engineers have analysed the electrostatic behaviour of hydraulic filters in critical oils thoroughly.

Fig. 6: HYDAC Electrostatic Test Rig

This has led to the development of the Stat-Free filter element series which combats the problem of electrostatic discharge. The elements are not only designed to be discharge-capable, but by means of special media combinations, they also reduce to a minimum the charge generation of the filter and the oil (see *Fig. 7*).

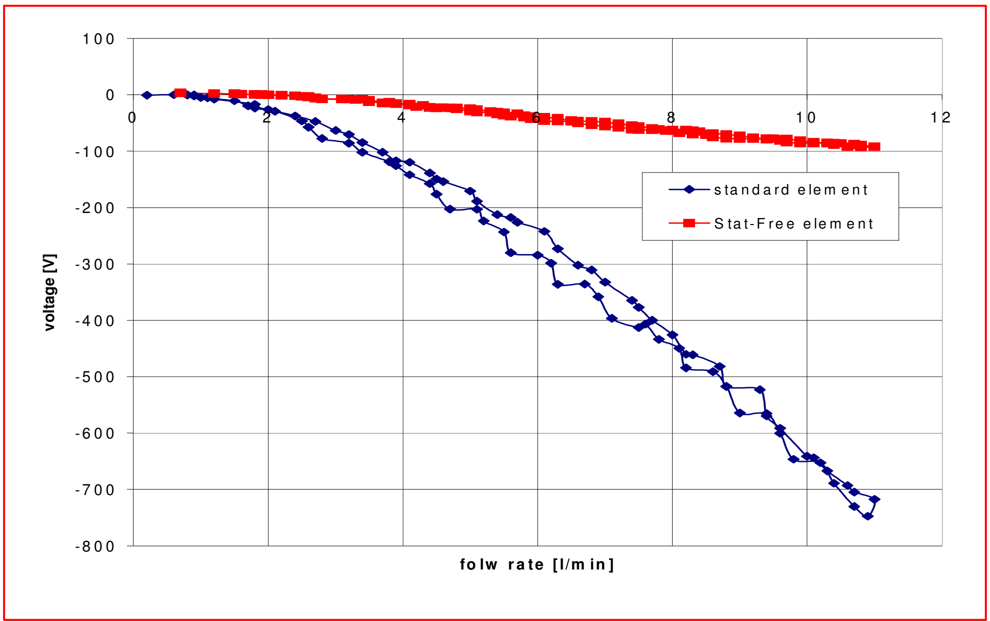

Fig. 7: Comparative measurement of a standard element versus a Stat-Free element

A purely discharge-capable design without the addition of a special combination of media, indeed reduces sparking in the element but the oil continues to be charged. The charges at the interface of the filter can dissipate, but the fluid has an even higher charge because there is no sparking on the filter to neutralize the charge. The highly charged oil is carried downstream through the system. Uncontrolled discharges are possible in other parts of the system which under certain circumstances can lead to serious damage (e.g. explosion in the tank). With the unique Stat-Free element technology, HYDAC has eliminated not only the consequences of electrostatic charging, but the cause itself as well.

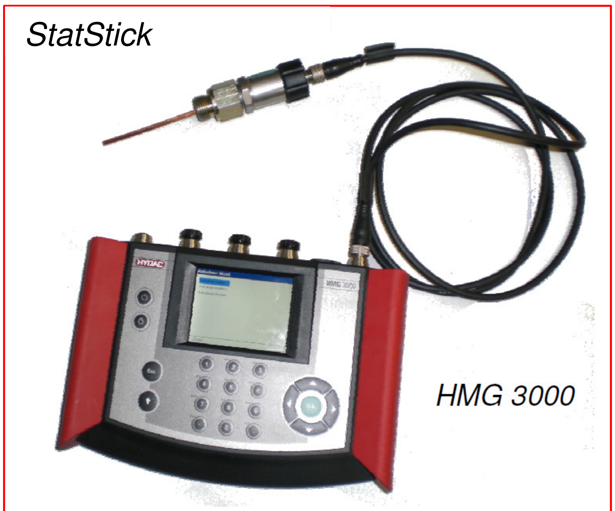

Fig. 8: StatStick with HYDAC HMG 3000

In order to analyse the behaviour of the filter, special sensors have been developed. Using the so-called StatStick the voltage in the oil after the filter can be measured (see Fig. 8).

With the help of the StatStick, HYDAC application engineers can carry out field measurements on electrostatic charging.
For example, HYDAC became aware of the possibility of explosions in the hydraulic tank on a big hydraulic system after breather filters were completely burned out (see Fig. 9). The filters concerned were competitor's filters which were not optimized for electrostatic charging. Measurements made on site using the StatStick revealed voltage peaks of up to 17,000 Volt and dangerous discharge sparks in the tank. Once retro-fitted with Stat-Free elements, no further discharges could be detected and the voltage was just 2-3 Volt (see Fig. 10).

Fig. 9: Burnt breather filter

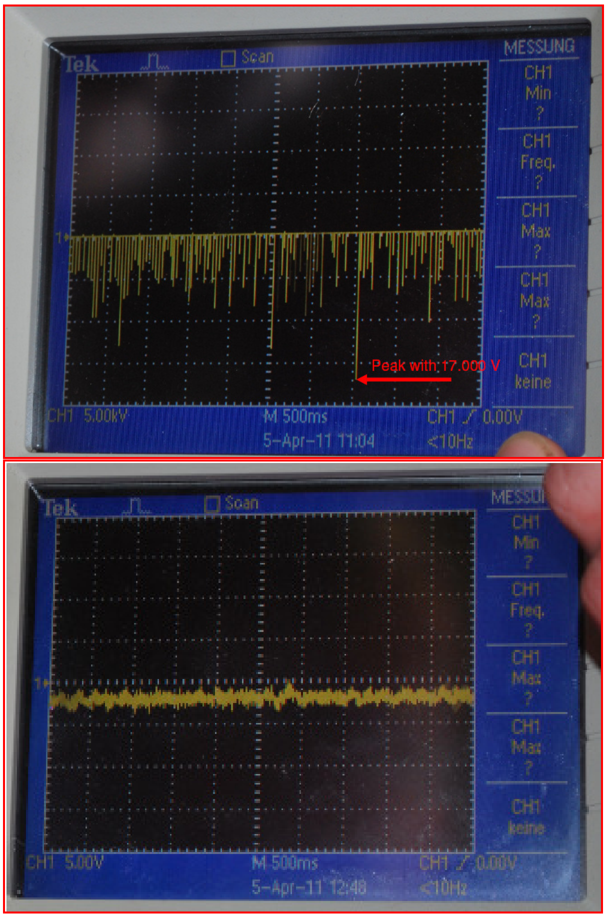

Fig. 10: Voltage measurement using StatStick (above: competitor's standard element voltage peaks up to 17kV [scaling 5kV]; below: Hydac Stat-Free element 2-3V [scaling:5V])

3 Varnish

3.1 Cause

Varnish is the product of chemical reactions in the oil. These chemical reactions which are also often called oil ageing, accelerate significantly in the presence of local hotspots in the oil (>300 °C). Electrostatic discharges are often a source of such high temperatures. Other hotspots can be caused by micro-dieseling or hot components (see Fig. 11).

Fig. 11: Thermal image of a local hotspot in the hydraulic system

The mechanism of oil ageing in these cases is always the same. The base oil consisting of hydrocarbon chains is cracked by high local temperatures, or in effect, broken apart. A radical structure is created which quickly reacts further. The radical hydrocarbon chain sections react with other hydrocarbons, oil additives or with oxygen. At the end of this reaction, a long chain develops, also called varnish, which is deposited as oil sludge in the hydraulic or lubrication oil system.

Modern oils in group II - IV contain numerous additives which improve the characteristics of the base oil, for example, viscosity index, corrosion protection, foaming tendency, adhesion characteristics and oil ageing behaviour (antioxidants). The oil ageing behaviour is affected mainly by two substances in the additive package, namely phenols and amines. These two substances act as radical scavengers and interrupt the chemical reaction of which the final result is varnish in the oil. In doing this, however, the radical scavengers become depleted. If they are exhausted, oil ageing progresses very rapidly. The level of amines and phenols which reveals the ageing condition of the oil cannot be detected using traditional measuring methods. New measuring methods, such as the RULER^{TM} (Remaining Useful Life Evaluation Routine) test or the MPC (Membrane Patch Colorimetry) test, are required to establish the ageing condition of the oil.

3.2 Consequences

The consequences of a rapidly ageing oil which is also developing varnish are varied. Varnish is deposited on technical components in the hydraulic system, for example on the tank or on hydraulic valves. If the valves are jammed, the hydraulic system can fail very quickly. In addition, varnish is an insoluble soft substance which rapidly causes blinding in standard hydraulic filters, often within a few hours. If the level of antioxidants is below 60-80%, a complete oil change should be carried out.

3.3 Solution

If there is an acute problem with varnish in the hydraulic system e.g. filters or valves become blocked, there is the option of using special filters such as for example, the IXU from HYDAC. In contrast to standard hydraulic filters, the principle behind this filter is not a mechanical but a chemical process. The oil flows through a special resin which absorbs the oil ageing products and effectively removes them.

Fig. 12: HYDAC Ion eXchange Unit (IXU)

However, this does not eliminate the cause, i.e. the formation of oil ageing products. Stat-Free filter elements can be used to combat rapid oil ageing. The electrostatically optimized elements prevent discharges in the oil and the associated formation of oil ageing products. Depending on the system, a fall in the oil temperature can also bring about a significant deceleration in oil ageing.

Permanent oil monitoring offers the possibility of having accurate information on the condition of the oil. A reliable procedure for determining oil ageing is the RULER™ test, which is carried out in the FluidCareCenter® at HYDAC Filtertechnik. Basically this involves comparing the level of antioxidants in a sample of used oil to that of fresh oil and determining the maximum remaining life of the used oil.

4 Conclusion

When using modern zinc-free and ashless hydraulic and lubrication oils with low electrical conductivity, electrostatic phenomena can occur in the system and the formation of oil ageing products escalates. Serious consequences such as explosions in the tank, sludge formation in the oil and the breakdown of components are possible.

Stat-Free filter elements are used to prevent electrostatic charge generation and therefore ensure safer operation of the system. When the oil ageing is advanced, a costly oil change can be avoided by using chemical filter systems (HYDAC IXU). To prevent the oil condition from deteriorating, regular oil sample analysis is advisable using the RULER™ procedure.

Sources

[1] Lüttgens, Günter / Boschung, Pierre: Electrostatic Charging – Causes and Elimination, Grafenau 1980, Page 17 – 76.

[2] Lüttgens, Günter: Static Electricity. Renningen 2000, Pages 59 – 65.