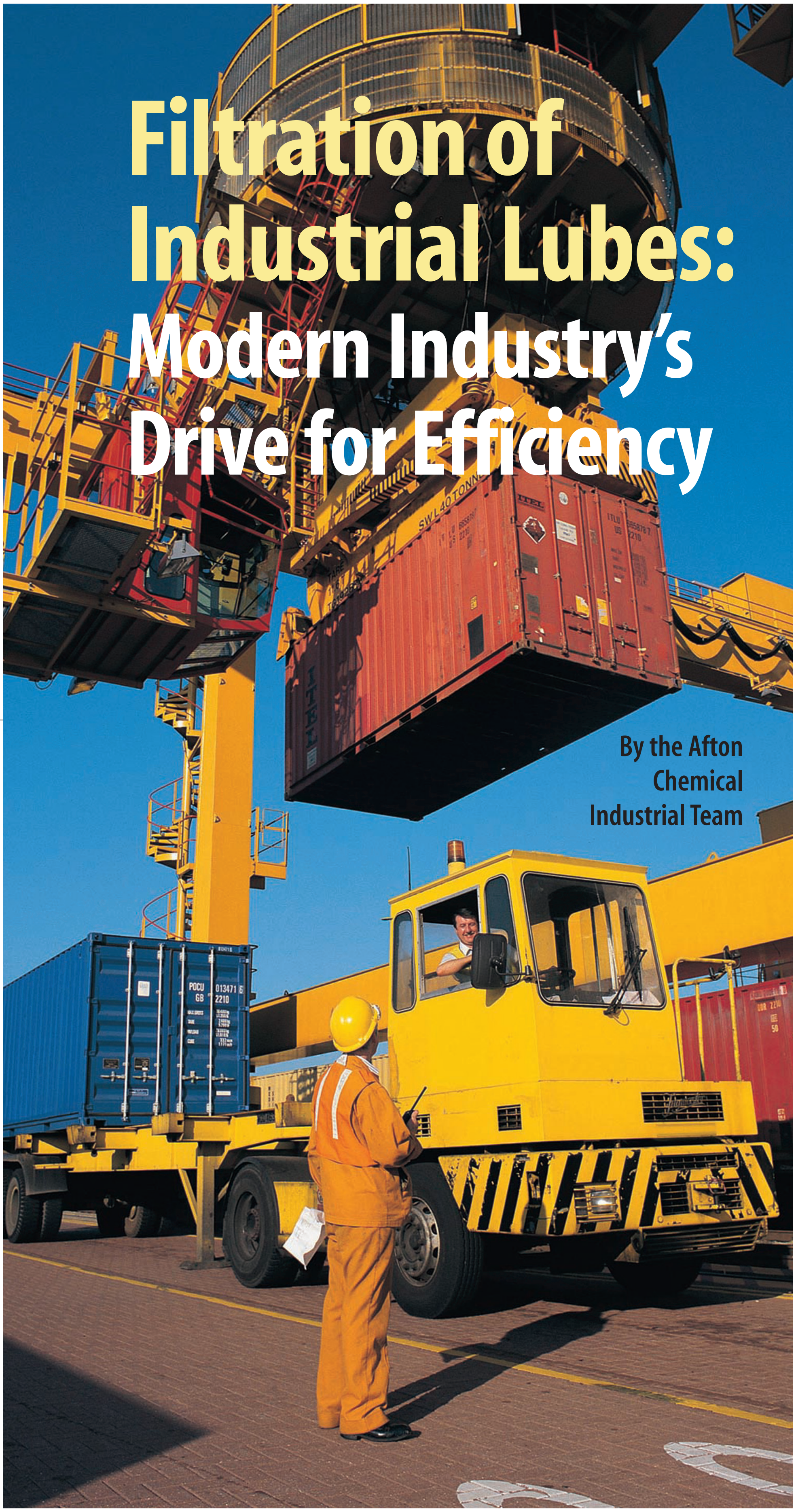
Filtration of Industrial Lubes: Modern Industry's Drive for Efficiency

By the Afton Chemical Industrial Team



Reduced maintenance and lower operating cost requires that industrial lubricants cope with some level of insoluble material which becomes apparent during use. The source of such debris or insoluble particles might be from contamination, poor housekeeping, oil degradation products or additive components, which have reacted, hydrolyzed or oxidized and become insoluble. There are several standards in the industry which deal with filtration properties of lubricants.

There are standards for the filter manufacturing industry that deal with dimensions, properties and performance of filter units. These include:

- **ISO 2943**: Verification of material compatibility with fluids.
- **ISO 396**: Evaluation of differential pressure vs. flow characteristics.
- **ISO 16889 (formerly ISO 4572):** Method for evaluating filtration performance of a filter element.

The ISO 16889 multi-pass test introduces a specified contaminant (Test Dust ISO-MTD) to access filter performance (beta-value, efficiency), dirt hold capacity, filter micron rating and differential pressure. For the filter industry, the ISO 16889 is one of the most important standards since it rates the filter performance. Only filters that pass can achieve the oil cleanliness level that is necessary for specific applications such as 18/16/13, according to ISO 4406 and as required in the AGMA 6006 for wind turbine gearboxes.

In addition to these standards, most of the filter manufacturers have non-standardized filter tests in place. Typical examples of these in-house tests would be the Hydac Dynamic Multi-Pass Test and the Hydac Cold Start Condition Test.

The cold start condition test is of particular importance for wind turbine applications where the ability to pump very cold oil is necessary. The most critical point under cold start conditions is the pump suction hose; also, the filtration with closed filter bypass must be enabled.

For the industrial lubricant formulator, filterability tests for oils are of high interest. Compatibility between the filter media and lubricant base oils and lubricant additives is critical for efficiency. One important standard in this area is the ISO 13357-1 & -2 test as shown in Figure 2.

The test is a single-pass test using a 0.8 µm filter patch. The test runs two stages, and the result for each of the stages is referred to as "Filterability." Filterability is a dimensionless number which is the ratio expressed as a percentage between volumes (Stage I, compares Videal to Vreal) or flow rates (Stage II, compares Qstart to Qend) at specified intervals.

The ISO 13357 standard was initially developed for filterability testing of hydraulic fluids of viscosity grades less than or equal to ISO VG 100. For gear oils, which typically have viscosity grades higher than ISO VG 100, this method has some disadvantages. The method measures tendency for filter plugging only, with results often near 100%, making it difficult to distinguish between many oils. Also, the 0.8 µm filter patch is too fine for gear oils and the flow rate itself is not assessed.

Another national standard widely used in Europe is the NF E48-690, measurement of filterability of mineral oils. The NF E48-690 describes a test that is quite similar to the ISO 13357 test. It describes a hydraulic filterability test where time measurements are taken at specific filtrate volumes (50, 100, 200, and 300ml). The result is an Index of Filterability (IF). Calculated from the time measurements, IF is a ratio between the rate of filtration at the start and end of the test.

Also important are some of the OEM in-house filtration methods such as the SKF Filterability Test. The SKF Filterability Test is a single pass test in which 100 ml of oil is sucked through a 1.2 µm membrane filter by using a vacuum pump that provides a constant defined pressure.

The principle of the SKF test is used by many filter manufacturers such as Hydac, Internormen and Pall Corp. Hydac and Internormen use different filter material (e.g., MF-Millipore mixed cellulose ester), whereas Pall keeps the flow rate rather than the sub pressure constant.

Figure 1. Large viscosity differences even with typical gear oils VG 320

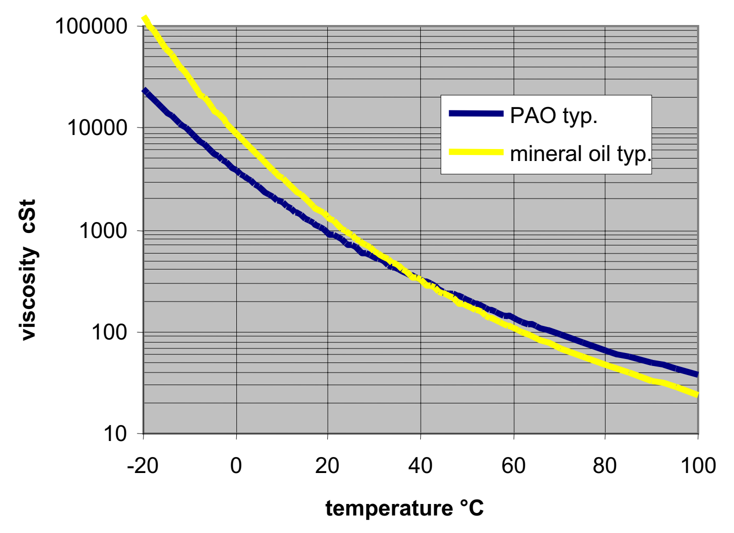
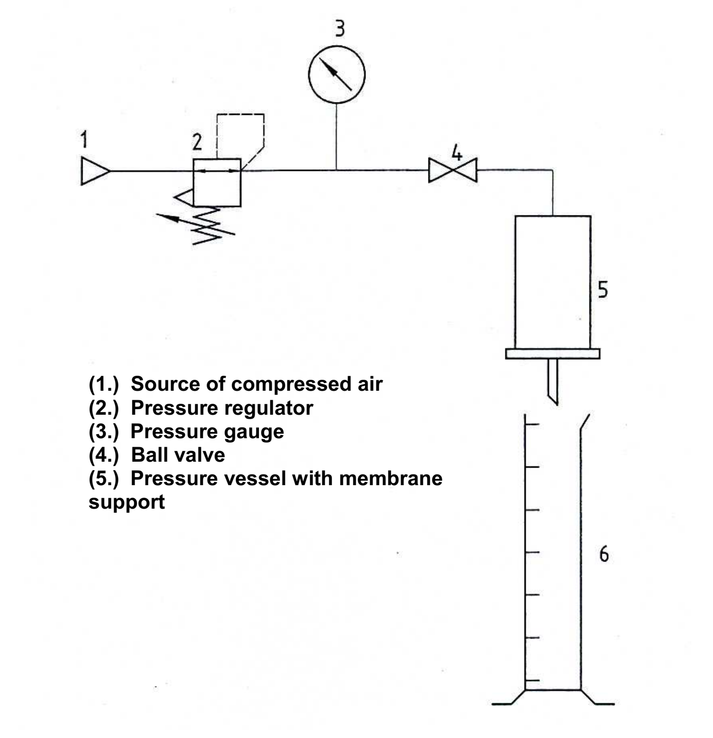


Figure 2. Schematic of ISO 13357-1 & -2 test



(Graphs courtesy of Dr. Armin Schmidt, Hydac)

A special OEM in-house test is currently being developed at Hydac. This test looks at the impact of lubricant additive depletion, especially the depletion of antifoam additives through filtration. The test setup combines a Multi-Pass Filterability Test with a foam test. The first stage evaluates the foaming behavior of the fresh oil using Flender's foam test procedure. The oil is then filtered in the second stage followed by another Flender foam test.

Figure 3 on page 22 shows a good example of a poor performing oil. The fresh oil,

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identified by the red line, immediately shows borderline performance. After filtration the foam properties get significantly worse with foam strongly increasing. The development of this new test method was mainly driven by the wind turbine industry, where severe foaming problems in the field have been observed with fluids that gave good foam performance when new. The test results seen so far confirm that there are large differences between the foaming characteristics before and after filtration for different oils.

Another important OEM test is the Parker Hannifin France (formerly Denison) TP021 Filtration Test. This test was developed to evaluate the filterability of petroleum-based and synthetic hydraulic fluids. Parker Hannifin saw a need to develop a filtration test since filtration of hydraulic systems is hindered by the presence of small quantities of water (typically <2%). Consequently, the test sample is filtered both as is and then with the addition of 2% v/v water. The filtration itself is carried out under a vacuum (26-inch Hg/-1bar) using a 1.2µm (47-mm diameter) MCE, MF Millipore filter. The filterability is determined by the time it takes to filter 75ml of sample and should not exceed 10 minutes.

Figure 3. Hydac in-house filterability tests

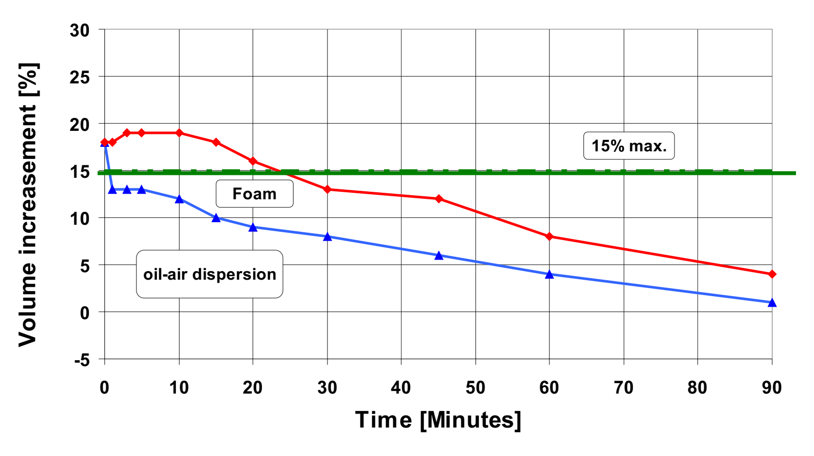
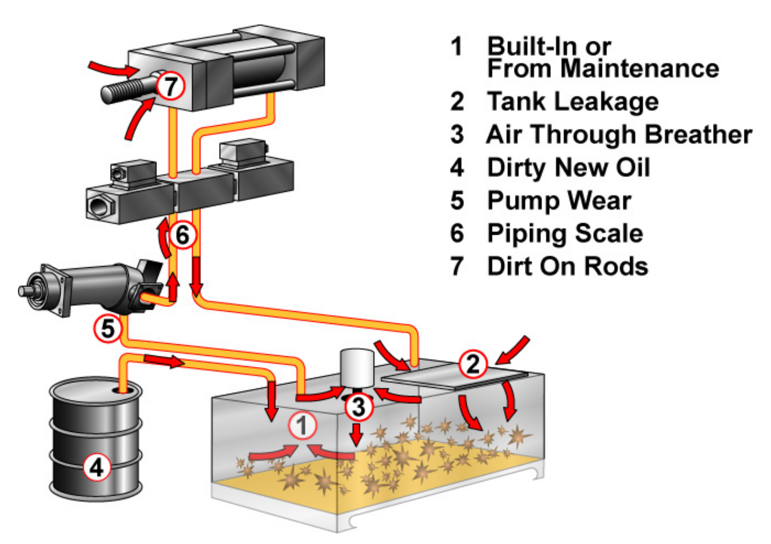


Figure 4. Sources of contamination



(Graphs courtesy of Dr. Armin Schmidt, Hydac)

Sources of contamination

There are several sources of contamination of lubrication circuits. As identified in Figure 4, there are 7 key areas. Below is a description:

(1.) **Built-in or from maintenance.** Debris from cutting, grinding and welding processes, pieces of gasket material or from semi-liquid sealant materials can hardly be avoided at the construction and assembly process. Opening a system for maintenance purposes will bring dirt from the environment into the system. Preservation materials from replacement parts often contaminate the system as well.

(2.) **Tank leakage.** Environmental dust and water ingress can lead to contamination if the system reservoir is not properly sealed.

(3.) **Air through breather.** If a breather system is not properly filtered, air borne particulates from the atmosphere can get into the system. Water ingress can be caused through atmospheric condensation inside the reservoir.

(4.) **Dirty new oil.** Ideally, a new fluid should be clean. However, every time something is done with the fluid, such as blending, pumping and packaging, contamination can occur. Another potential source of contamination is the transfer of the fluid from its delivered package to the lubrication system. To avoid further possibility of contamination, workers should make sure their hands are clean as well as the electric-driven pumps, hoses and vessels.

(5.) **Pump wear.** Normal pump wear can generate metallic particulates. Once there are solid particulates in the system they will give rise to even more particulates from further abrasion. If the system is not correctly filtered this type of contamination can significantly reduce the lifetime of the system.

(6.) Piping scale. Deposit formation on the inner side of the piping leads to permanent contamination. Deposits such as sludge, gum and varnish can be formed from fluid oxidation, polymerization and condensation reaction products. Another source for deposit formation could be corrosion.

(7.) Dirt on rods. There is always a thin oil film on the rod at the end of a hydraulic cylinder which generally contains dirt coming from the working environment. Once the rod is retracted, some of the dirt may pass the seal and get washed off by the fluids inside the cylinder. This effect is higher in some systems where the condition of the rod seal may be poor.

Reducing electrostatic discharge

As we discuss filtration, various methods of removing contaminants and techniques for inhibiting sludge and varnish build-up, it is important to note a method of filtration that does not simply remove contaminants by physical size exclusion or centrifugation. There are in use today methods of lubricant cleaning that involve the use of electrostatics. For many the idea of electrostatics, in relation to lubricants, conjures up visions of static build-up from high-velocity filtration, bearing distress due to electrostatic discharge (ESD). One may think of sludge and varnish formation due to the high temperatures associated with sparks, damage to mechanical filters due to sparking, and in the worst cases, explosions. There is, however, a use of electrostatics in the filtration of fluids that is proving very beneficial in certain applications.

Small contaminants, like dust, dirt and the by-products of oil degradation have a property in common. Namely, these materials tend to be polar in chemical nature and sensitive to electrostatic charges. One technique available today for removing these contaminants is the use of oppositely charged plates between which the lubricant flows at a relatively low velocity. Positively and negatively charged contaminants are drawn to one or the other of the two charged plates as illustrated in Figure 5.

In the process they become trapped in a filter material. In a second technique referred to as "balanced charge agglomeration," the charge character of the contaminants and polar materials is enhanced by passing the lubricant through an electrostatic charging system as shown in Figure 6 on page 24. The enhanced charging of the submicron contaminant and oil degradation particles causes them to stick together, clump and agglomerate into particles of such a size that they are more easily removed by standard size exclusion filtration systems.

These applications of electrostatics to filtration are becoming increasingly important as equipment and processes are more closely scrutinized for areas of improvement and root causes to equipment failure. In both of these techniques, there have been reports of considerable success not only in cleaning up a contaminated and degraded fluid, but also cleaning up over time the varnished parts of the system.

Proper additive selection

Filtration performance is impacted by lubricant additive selection. For example, acidic additives selected to prevent rust can interact with detergents in the presence of water to form precipitates that block filters. Any precipitates formed, whether they are from reactions, interaction with metal parts or

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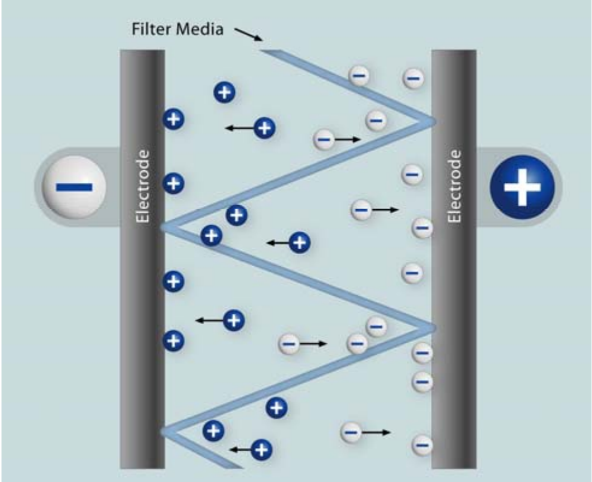
Figure 5. Electrostatic filtration



During low velocity flow through the filter, positively and negatively charged contaminants migrate toward the oppositely charged electrodes and become trapped on the filter media or electrode surface.

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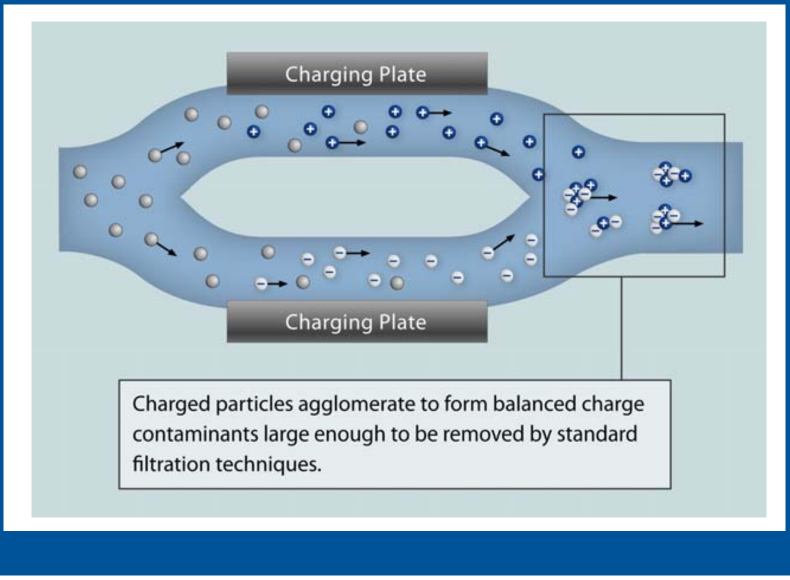
Figure 6. Balanced charge agglomeration



Charged particles agglomerate to form balanced charge contaminants large enough to be removed by standard filtration techniques.

aging, in use when they fall out, will put out demulse and foam additives that act on the interface. In particular, additives are selected to resist hydrolysis which can lead to precipitation of metal salts and other species.

Attention to the selection of any polymers used such as pour point depressants and viscosity index improvers (VII) also is important. These polymers, if not manufactured correctly, can de-rate filtration performance significantly. Filtration problems seen with pressure build-up across the filter have been reported by some pump OEMs which result from poor selection of viscosity index improver. The absence of cross-linked impurities, which can even form during service, is important when considering VII selection.

Conclusion

The complexity of the industrial lubricant industry is seen in many areas. The interaction between the fluid and the filters is being given more and more attention as operators and OEMs alike strive for efficiency and reduced downtime. Filter manufacturers, system designers and lubricant/additive manufacturers are all working to improve the filtration performance of these systems. <<

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