Hydraulic System Contamination Control

Fluid power has long been the first choice in operating both industrial and mobile machinery. Producing high output forces with great accuracy and repeatability have been the main reasons behind this. However, hydraulic systems can fail and be seriously damaged when contamination of the hydraulic fluid in these systems occurs. This article explores what contamination in a hydraulic system means. We will touch on prevention and proper maintenance as well as types of filtration and proper system design involved in contamination control. (Eleftherakis & Norvelle, Preface, p.3)

Contamination can be defined as anything in a system that is not supposed to be there. The most common contaminants are solid particles (normally lumped together as “dirt”). Heat, air, gas, chemicals, water, and many others are found in hydraulic fluids. “Dirt” in many forms can be found in hydraulic oil. These include sand, silica, seal material, thread tape or sealers, wood fibers, rags, oil absorbent materials, and any other solid material. (Ch. 2, p.1)

The dimensions of particles in hydraulic fluids are measured in micrometers. One micrometer is one millionth of a meter, or approximately 0.0000394 in. This means that there are 25,400 micrometers per inch. The term micron is usually written as μm. The word micron is normally used instead of micrometer. Particles in a system may be larger or similar size to that of a given clearance of a system component. If the particle is larger than the clearance, it may block the opening. If a contaminant is smaller than a given clearance, it might enter and then become wedged between the surfaces which could cause wear to occur or might cause the device to jam. (Ch. 2, p.2)

The smallest size particle that can be seen by the naked eye is 40 μm at best. Most system components have much smaller clearances. Particles that cannot be seen without magnification can harm system performance, cause wear of the component, and can eventually force the system to fail. Therefore, a visual inspection of an oil sample from a hydraulic system may not indicate a problem, even though the fluid may be highly contaminated. (Ch. 2, p.3)

The systemic approach to contamination control starts by defining your cleanliness goal for your system. This should be to clean the fluid to a point where contamination is not a factor in the failure of any component in that particular system during the useful life of that system. The setting of the target cleanliness level is next. This would take into effect the specific needs of that system.

Now that the cleanliness level has been set, the selection and placement of the filters in that system are done to achieve the stated goal. This requires an understanding of 3 factors; filter performance, circuit dynamics, and filter placement. Contamination problems in many systems can be traced back to either poor filter placement or the inability of the filter elements to maintain their performance levels throughout the life of the system. (Ch. 1, p.3)

Proactive maintenance requires that an oil sampling and testing program be put in place for each hydraulic system. This involves taking oil samples from the system and sending them to a particle counting laboratory that gives cleanliness code data to establish standards. If the target is being met, then the machine only needs to have regularly scheduled testing and the filters maintained. If the target is not met, then corrective actions are necessary. This could include shifting to a finer grade of filter media. Also, sources of ingression (where contamination enters the system from the outside) should be checked and fixed.

One way of classifying hydraulic oil filters is by the type of filter assembly used. The two assembly types are spin on and cartridge. Spin on filters consist of two parts. The filter head is permanently mounted in the system. The filter canister contains the filter medium. The canister is removed and replaced when changing a spin on filter. The removed canister can be discarded.

Cartridge filters are made up of three parts. The filter head is permanently mounted. The filter bowl is screwed into the head. A filter element is placed inside the bowl. With cartridge filters, the element is removed and replaced while the bowl is reused.

Most filters in use are some form of paper (cellulose). Often, they include some material such as resins or fiberglass to strengthen their non-woven structure. Some man-made synthetic materials are used for filter media. These materials have an advantage over the cellulose media because their fiber diameters and length can be closely controlled while cellulose fibers are random in both size and length. (Ch. 8, p.7)
A filter rating is used to describe the ability of the filter to remove particles from the fluid stream. Sometimes this is noted as a particle size, like 10 micron for example. Two other terms that were used were absolute and nominal ratings. None of these are utilized much today as they have been deemed unreliable and misleading.

The international standard for rating the efficiency of hydraulic and lubricating filters is the Multipass Filter Performance Beta Test (ISO 4572). In this test, fluid that is continuously injected with a standard contaminant (AC Fine Test Dust) is circulated through the test filter using a test stand. At specified intervals through the test, based on the pressure drop across the filter element, fluid samples are extracted upstream and downstream of the filter until a specified terminal pressure drop is reached. An automatic particle counter is used to determine the particle size distributions of these samples. The Beta rating of the filter is the ratio of the number of particles of a given size or larger in the upstream sample (nu) to the number of particles in that size range in the downstream sample (nd), or,

\[ \frac{\text{nu} \geq x \text{ microns}}{\text{nd} \geq x \text{ microns}} \]

where X defines the particle size of interest. Therefore, a filter rating of \( \beta_{10}=15 \) indicates that the upstream to downstream ratio of the number of particles 10 microns and larger is 15. In other words, for every 15 particles 10 microns and larger that enter the filter, only one passes through it. The higher the Beta rating, the more efficient the filter.

The Beta rating can be expressed as a capture efficiency by the equation;

\[ \text{Eff} = \frac{\beta - 1}{\beta} \]

The efficiency of the filter in capturing particles 10 microns and larger in the example above is \( (15-1)/15 = 0.93 \) or 93%. The Beta rating is the only internationally recognized and accepted filter rating method and should always be used in evaluating filter performance. (Ch. 8, p.11-12)

Dirt holding capacity of a filter is also an important measure of a filter element. The ISO 4572 standard requires that this capacity be calculated at the end of the multi-pass test. Since the ACFTD contaminant is injected at a known rate throughout the test, the value is just the injection rate multiplied by the duration of the test. It defines the amount of ACFTD required to raise the pressure drop across the filter to the terminal value. However, this defines only the amount injected and not necessarily the amount captured by the filter. A more accurate evaluation of dirt holding capacity can be obtained by conducting a gravimetric analysis to determine the amount of ACFTD still being circulated in the fluid at the end of the test. Subtracting this value from the amount of ACFTD injected shows the amount actually captured by the filter.

There are three main places in a circuit where contamination control filters should be located: Pressure line(s), Return line(s), or Recirculating loop. A pressure line filter should be fitted directly downstream of any fixed volume pump operating over 2250 psi (155 bar) and any variable volume pump operating over 1500 psi (103 bar). An operating pump is always producing some wear debris. Systems with servo or proportional valves should have a high pressure filter regardless of pump type or pressure. The pressure line filter can be considered the total system contamination control device only if it sees maximum pump flow during more than 60% of the machine duty cycle. (Ch. 8, p.13)

The return line is a good location for the main system filter, as long as there is at least 20% of system volume each minute flowing through it. When the return line flow is less than 20% of system volume, a supplementary recirculating pump and filter should be designed into the system. (Ch. 8, p.14)

“We come across many contamination problems at our customers’ plants,” said Don Roberts, Field Service Manager. “Sometimes we see where the filler strainer has been broken when they went to add oil to the reservoir. A dedicated fill line can help solve that problem and control the ingestion that occurs because of improper filling techniques. Of course, filling your tanks with new oil, without filtering that new oil first, will add contaminants to your system.”

“We have implemented oil testing in several instances and find that in doing in conjunction with regular replacement of the filter elements are much more economical than the constant replacement of pumps, cylinders, and valves in a hydraulic system. Places where we have implemented the oil testing service and the customer regularly changed their filters and elements, has resulted in much longer life of components in their hydraulic systems,” said Roberts.
At Sentinel Fluid Controls, we offer a full line of Eaton and Internormen hydraulic oil filters and replacement elements to meet your needs. We also carry the Eaton Hydraulic Fluid Analysis Service for your fluid monitoring programs. Our engineers will help in the design of hydraulic systems and SFC Field Service will travel to your place for troubleshooting and repair. Contact Steve Gage, Corporate Sales Manager today at (262) 796-9800 ext. 222 to be directed to your assigned Territory Manager!


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