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Hydraulic Filters

The article explores the topic of hydraulic filters for educational use and is presented here to refresh your memory. Hope you are able to recall the constructional features, performance specifications, and location-based installation details of hydraulic filters quickly. Let us get down to the nitty-gritty of hydraulic filters…

Introduction

Modern high-pressure hydraulic systems with components built to closer tolerances are susceptible to many types of contamination. Contaminants can cause the premature wear of internal surfaces. They also promote leakage and clog the flow paths. Therefore, an efficient and appropriately-sized filtration system should be an integral part of every hydraulic system to separate the particulate matter of a specified size or greater from the system fluid. They should be fitted at appropriate locations in the hydraulic circuit for the effective control of contamination.

Strainers and Filters

A filtration unit, such as a strainer or a filter, basically consists of a filter element encased in a housing. It also includes necessary seals and ports. The filter element captures the contaminants in the fluid stream that passes through it. The fluid flows through the filter element either the so called 'in to out' or 'out to in' fashion. The filter housing protects the filter element. A filter can be designed to pass the entire flow through its filter element in each cycle (as in a full flow filter) or to pass only a portion of the flow in each cycle (as in a proportional flow filter). The filter element, seals, and the housing must be compatible with the fluid medium.

Strainer

A strainer is a coarse filtration unit consisting of an epoxy-coated stainless steel wire screen element. For petroleum fluids a strainer with a mesh width of 149 µ (100 mesh) is recommended. For all other fluids, a stainless steel wire screen with a mesh width of 260 µ (60 mesh) may be used. It is usually mounted to the open end of the pump intake line and is arranged in a horizontal position near the bottom of the system reservoir.

Filters

In addition to the strainer, fine filters should be added to a hydraulic system that uses sensitive components and operates in a dirty environment. The media in the filter unit is much finer than the wire screen. They are made of resin-impregnated paper (cellulose) or multi-layered, epoxy-bonded glass microfibers containing millions of tiny pores. Typically, the cellulose media are available in 3, 10, and 25 µ ratings and the glass fibre elements are available in 3 and 10 µ ratings. The media part of the filter is often pleated. The pleats can be made deeper and large in number to give the element more surface area for efficient filtration. This type of filter media absorbs contaminants throughout the depth of the media as the fluid flows through it.

Filter Assembly Choices

According to the assembly choices, the filter can be a spin-on type or a cartridge type. The spin-on type filter unit is a low-pressure, self-contained and permanent filter element (10, 25, 33, or 40 µ) and housing assembly which can be screwed on to the filter head. It is meant for use in pump suction and tank return lines. The cartridge type filter unit consists of a permanent housing with the replaceable filter element and is used for higher pressures and flows. The cartridge filter elements are available in many filtration ratings down to 1 µ.

Materials of Construction

The materials of construction of the filter media have already been discussed in a previous section. The filter housing is made of tinned or galvanized steel. The seals are made of the Nitrile Buna Rubber (NBR), as a standard, or optionally the Viton. The connections are usually made of nylon or aluminium. The filter unit may be provided with a magnetic column for attracting and holding ferrous particles too small to be picked up by any other means.

Filter Assembly with a Bypass Valve

The pressure differential across the filter element must not be allowed to rise too high so as to prevent the element from collapsing or bursting. A bypass valve can be incorporated in filters for protection against filter collapse/burst as a result of clogging of the filter element with contaminants. This filter assembly with a bypass valve is a type of relief valve that diverts all or part of fluid flow back to the system reservoir, once the permissible maximum pressure differential across the filter is reached.

Bypass valves are typically available with a 0.1 to 0.35 bar (2 to 5 psid) spring when the filter is used in the pump intake line. They have the cracking pressures typically in the range between 1 and 1.7 bar (15 and 25 psid) when it is used in the pressure line. They are typically available with a 1 bar (15 psid) spring when it is used in the tank return line.

The filter element collapse pressure/burst pressure may range from 3.4 bar (50 psid) to 10 bar (150 psid). The full-flow pressure drop across the bypass valve may be restricted to two-third of the collapse pressure/burst pressure.

Visual/Electrical Clogging Indicator

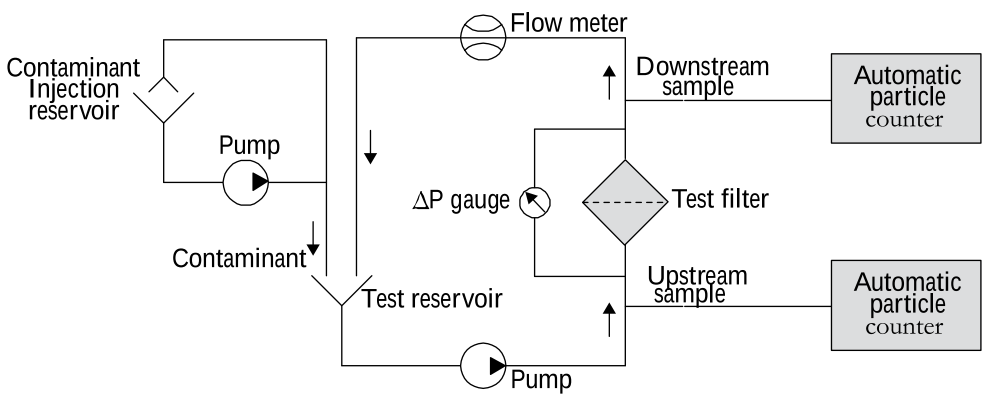
The filter can be provided with a pop-up visual clogging indicator or a pressure hydraulically-actuated electrical switch wired to a warning light to indicate when it should be replaced.

The Performance Specifications of Hydraulic Filters

The degree of cleanliness required of a hydraulic system fluid can be linked to the performance of the filter elements used in the system. A filter unit must be able to handle the system pressure as well as the flow. A filter element is rated on the basis of their ability to separate contaminants of a particular size and above from the system fluid, under the specific test conditions. Various parameters of the filter such as the Beta ratio, filter efficiency, micron rating, etc can be determined using the multipass test procedure.

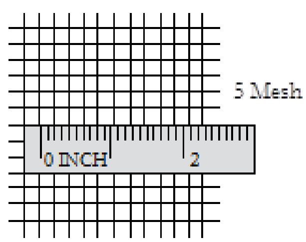
The Multipass Test

Since a single pass of a test fluid through a filter may not give a true indication of the filter's ability to catch particles of sizes greater than a specified value, it was considered necessary to recirculate the fluid many times through the filter. The multi-pass test gives reproducible test data for assessing the performance of hydraulic filter elements. This test provides an accurate and universally accepted test method to describe the efficiency of the test filter in removing particles of a standard test dust from the test fluid over a wide range of particle sizes, under controlled laboratory conditions similar to the operating conditions on the field. This test has been standardized by the ISO (ISO 16889:2008), SAE (SAE J1858), ANSI, and NFPA. The standardization allows the designer to compare published filter ratings among different brands of filters reliably so that a cost-effective filter system can be selected for a given application.



Mesh Number/Sieve Number

The mesh size or fineness of a wire-mesh filter can be expressed in terms of its mesh number or sieve number. It is the number of openings from the center of any one wire of the wire mesh to the center of a parallel wire one inch away.



Beta Ratio

The beta (ß) ratio is a measure of the filtration efficiency of a filter element. It is a way of stating the effectiveness of a filter for removing particles of a certain size or larger. It can be determined by monitoring the fluid contamination levels upstream and downstream of the test filter. It is the ratio of the number of particles larger than a specified size (Say, x µ) which enter a filter compared to the number of the same size particles which go through without being caught. That is,

$$\text{Beta ratio}_{(x)}\ (\beta) = \frac{\text{Particle count in upstream oil}}{\text{Particle count in downstream oil}}$$

Filter Efficiency

The filter efficiency is derived from the Beta ratio and both convey the same information. It is given by:

$$\text{Efficiency } (x) = [1 - (1/\beta)] \times 100$$

Beta Ratio Vs Efficiency

The chart below shows the Beta ratio Vs the efficiency relation. A higher beta ratio points to the higher particle capture efficiency.

Upstream particles ($\geq$x μm)	Downstream particles ($\geq$x μm)	Beta (ß) ratio	Efficiency $_{(x)}$	Remarks
10000	5000	2	50.0%	Nominal
10000	500	20	95.0%	
10000	133	75	98.7%	Absolute
10000	100	100	99.0%	--
10000	50	200	99.5%	--
10000	10	1000	99.9%	--

Micron Ratings

The micron rating indicates the ability of a filter element to remove a specified percentage of particles of a certain size.

- Absolute Micron Rating of a filter is the smallest size of particles it can capture in excess of 98.6% on the first pass through it.
- Nominal Micron Rating of a filter is the smallest micron size of particles it can capture in a specified quantity, in the range from 50% to 95% on the first pass through it.

Normally, wire mesh and cellulose media elements are nominally rated which means that they might be only 50% efficient at the rated micron size. Whereas, a filter with a glass fibre media is rated in the absolute term which means that it is efficient in capturing particles in excess of 98.6% at the rated micron size.

Particle Capture Efficiency

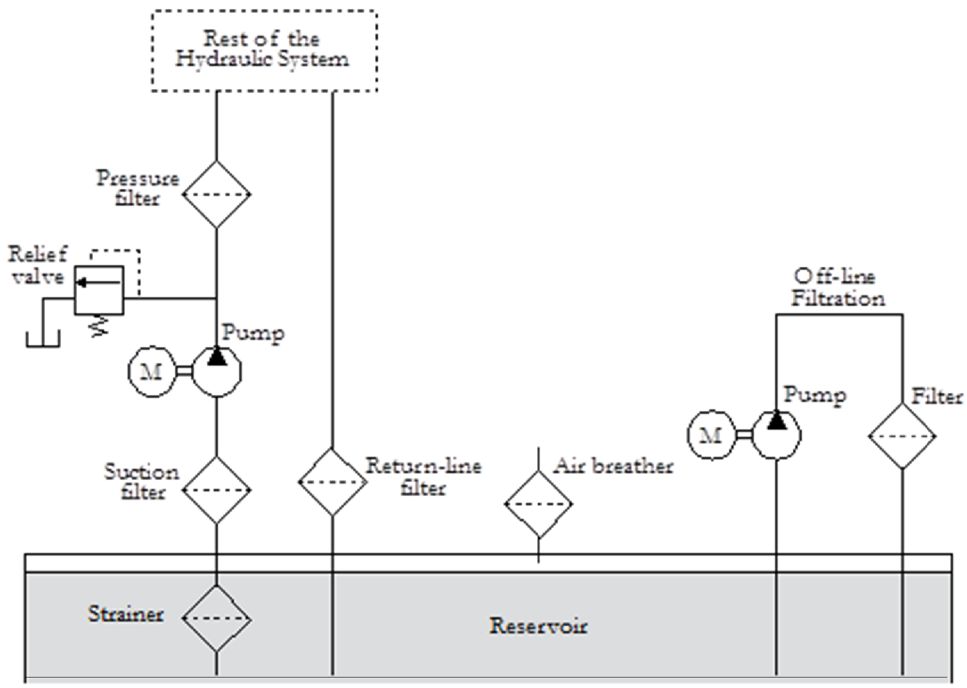
It is the weight of the specified artificial contaminant (ISO medium test dust) that must be added to the fluid upstream of a filter to produce a given pressure differential across the filter under the specified test conditions. It indicates the quantity of solid dirt that its filter element can hold before it needs to be replaced.

Differential Pressure (ΔP)

Differential pressure (ΔP) across a filter indicates the difference between its inlet and outlet pressures.

Filters According to Installation Locations

According to their locations in hydraulic systems, filters can be categorized into four types: (1) Suction strainers/filters, (2) Pressure filters, (3) Return-line filters, and (4) Off-line filters.



Suction Strainer

It is installed at the pump suction side. The openings in the strainer are usually greater than 149 μ (100 mesh). It provides protection to the pump from coarse particles, most economically. But, a blocked strainer can starve the pump, which, in turn, can cause cavitation. Moreover, it is difficult to clean the strainer. Suction strainers may not be very effective.

Suction Filter

Finer filtration can be employed in the suction line if sufficient filtration area is provided to keep the pressure drop within an acceptable limit. A suction filter is a coarse filter having a mesh width typically above 40 μ (400 mesh). A suction filter provides protection to the pump from coarse particles, economically. However, they offer only medium benefit to hydraulic systems. The suction filter is connected at the pump suction side in a service-friendly manner.

Pressure Filter

It is installed downstream of the pump. It usually sees the full system pressure as per the setting of the associated relief valve. It is constructed with the rugged casing to withstand the maximum system pressure. It can be smaller and finer (typically, 10 – 20 μ). The main function of the filter is to remove the internally-generated contamination in the fluid that comes directly from the pump. It serves to protect expensive and dirt-sensitive downstream components. Pressure filters offer high benefit. The filter should have an internal bypass valve with a cracking pressure of about one bar (14.5 psid) to protect the filter from collapse/burst.

Return-line Filter

It is installed in the return line, which may see no more than 20 to 30 bar (300 to 435 psi). It is usually a low-pressure housing. It is used to remove particles of typical size $\geq 25\mu$ in mineral-based fluids and $\geq 10\mu$ in synthetic fluids. The purpose is to trap dirt from the system working components, as well as particles, if any, entering the system through the worn piston-rod seals in the system. They offer high benefit. However, they may be subjected to flow surges while in operation. A relief valve may be connected to the filter to provide an additional path for the excess return flow if any.

Off-line Filtration

It is a subsystem independent of the main hydraulic system. It consists primarily of a separate pump and filter unit with quick-disconnect couplers and fitted on a mobile cart. It is relatively easy to retrofit on an existing hydraulic system. It can also serve many hydraulic systems. It is used to achieve the best possible filtration results in hydraulic systems. In this system, fluid is pumped out of the reservoir, passed through the filter, and allowed to return to the reservoir in a continuous fashion. It utilizes low-pressure housings that can easily be serviced. Off-line filters offer high benefit to hydraulic systems.

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Reference:

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(3) Manual on 'Hydraulic Filters - Size: 3/4" to 2½"', VELJAN HYDRAIR LIMITED, www.veljan.in
(4) Catalog on 'Hydraulic & Lubrication Filters - Part II: Proper Filter Sizing', HY-PRO FILTRATION, www.filterelement.com

Note: A comprehensive account of the topic is given in the textbook on 'Industrial Hydraulic Systems-Theory and Practice' by Joji Parambath.