TECHNI/TIPS

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LEADERS IN LUBRICANTS NUMBER 62

HYDRAULIC OIL FILTRATION

Seventy-five percent of hydraulic system failures are caused by contaminated fluid. This is not an exaggerated statement. Contamination causes extensive fluid system failures which lead to:

- Lost Production
- High Maintenance/Labor Costs
- Interrupted Production
- Expensive Component Replacement
- Possible Personnel Injuries

Although system failures cannot be completely eliminated, they can be substantially reduced through proper filtration. Since fluid maintenance, which includes filtration, is an expected maintenance item, it can be scheduled to fit production demands.

CONTAMINATION

Contamination is defined by the American National Standards Institute (ANSI) as, ***Any material or substance which is unwanted or adversely affects fluid power systems or components, or both***. Some substances which may be defined as contamination, depending on the system in which they are found, are as follows:

Liquid-Acid from oil degradation, water (from condensation, cooling system leaks, environment), chemicals used in production processes. Lubricants other than that contained in the system may also be considered contamination, since lubricant mixing often leads to incompatibility reactions, especially when dealing with synthetics such as esters and polyglycols.

Metallic-Machining chips, grinding particles, pieces of wire. Metallic particles can cause system component dam-age. Metallic particles also tend to become "gummy" when lodged in clearances and if magnetic, can hamper solenoid valve operation.

Nonmetallic-Airborne dust, casting sand, carbon, plastics and polymers. Nonmetallic contaminants include metallic oxides such as rust, abrasive airborne contaminants which can cause wear in pumps and valves, and polymers, which although soft in nature, can cause system deposit formation and act as catalysts for the oxidation process.

Fibers-Fibers from rags, airborne lint and bacterial growth. Although usually soft in nature, fiber type contamination may have an effect on system component clearances which in turn can hamper system operation.

General effects of contamination are system deposits and wear. System deposits are becoming increasingly critical as hydraulic system designs incorporate closer tolerances. Deposits can affect these tolerances and cause erratic system operation. Wear increases internal leakage and decreases the efficiency of pumps, motors and actuators. Wear also robs pressure controls and flow controls of their accuracy, causing inefficient and inaccurate operation.

SOURCES OF CONTAMINATION

Although fluid power systems are considered closed systems, they are not immune to contamination. Every event during the manufacture, storage, assembly, startup, breaking, operation, shutdown and maintenance of the system can introduce contamination into it, or generate contamination within it.

Contamination sources can be generally classified as either external or internal, depending on whether the contaminant originates from outside or within the system. Some typical contaminants and their classifications are as follows:

Contamination from External Sources

Category	*Sources*	*Typical Size in Microns*	*Most Common Form*
Implanted	**Built-in during manufacture of components and assembly of sys-tem due to:**		
	Environment:	**1-500**	**Airborne dust and dirt. Rust and other forms of corrosion.**
	Manufacturing Process	**1-500**	**Casting sand, drawing and buffing compounds, weld slag, machining chips, loose burrs, elastomeric particles from O-rings and gaskets, adhesives and paints.**
	System Fluids	**3-10**	**New, but contaminated fluids.**
Ingested	**Operating Environment**	**1-30**	**Airborne dust and dirt, moisture, gases and chemical fumes.**
Induced	**Introduced during maintenance and repair**		**Same as those described under "Implanted"**

Contaminants from Internal Sources

Category	Sources	Typical *Size in Microns*	*Most* Common *Form*
Generate	**System and system components due to:**		
	Adhesive wear (galling)	**5-750**	**Metal particles and chips.**
	Abrasive Wear (in oil)	**5-250**	**Metal, rust, plastic and elastomeric particles.**
	Surface Fatigue	**5-50**	**Metal particles.**
	Cavitation & Erosion	**40-250**	**Metal particles.**
	Chemical Reactions	**5-150**	**Rust and other forms or corroded metal (mainly metallic salts).**
	Electrolysis	**5-150**	**Metallic scales and particles.**
	Fluid Degradation by:		
	Overheating		**Varnish and carbon.**
	Oxidation		**Acids and sludge.**
	Moisture Contamination		**Metallic scales and sludge**
Escaped	**Filters unloading previously**	**0.2-750**	**Any of the above trapped contaminants**

FILTRATION PROCESS & MEDIA

Filtration is the physical or mechanical process of retention of particles in a fluid by the passage of the fluid through a medium. The size of the particles retained can be broadly classified as follows:

- Macro filtration retains particles greater than 2 um in size.
- Mirco filtration retains particles in sizes from 0.2-2 um.
- Ultra filtration retains particles in sizes 0.2 um and smaller.

Filtration is accomplished by one or both of two basic mechanisms:

- Depth retention
- Surface retention

Both rely in varying degrees upon two phenomena (See Fig. 1):

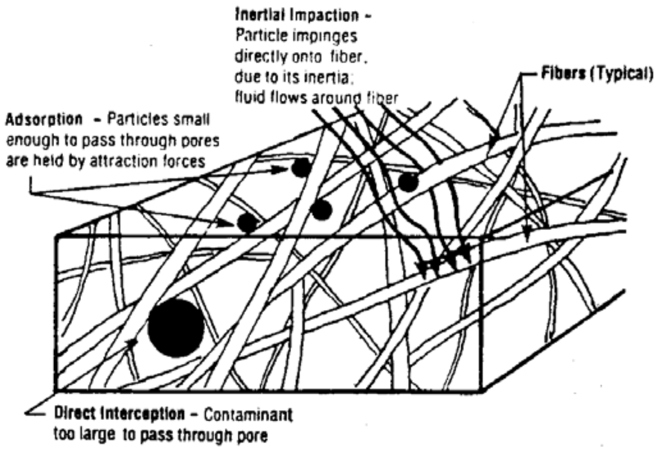
- Direct Interception: Particle retention due to the contaminant particle being larger than the filter opening.
- Adsorption: Attraction and/or retention of contaminant particles by electrostatic forces of molecular attraction.

Depth Filtration

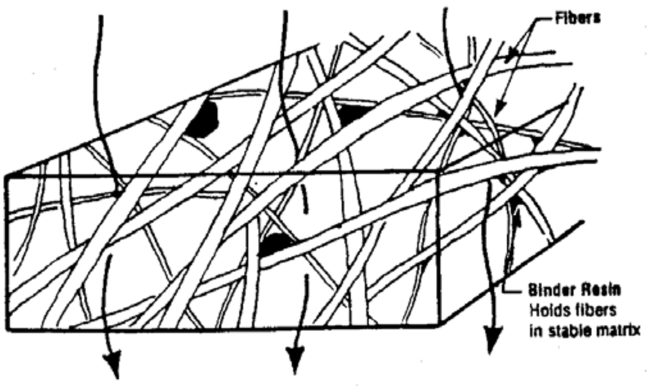
Depth filtration is the prevalent type used in fluid systems. It is considerably more complex than surfaced filtration, incorporating both direct interception and adsorption. Adsorption is the predominant capture mechanism in depth filtration, but considerable direct interception may occur; depending on the binding of the filter constituents. Depth filtration media can be categorized into three general types: fibrous, porous and cake-type, with fibrous being the most common in fluid systems.

1. Fibrous type media consists of a mat of very fine fibers (See Fig. 2). These fibers are commingled and intertwined so that numerous flow passages or pores, in which contaminants can be retained, are formed. Fiber materials most commonly used are:

Cellulose
Cotton
Micro Fiberglass
Synthetics, such as rayon or polypropylene



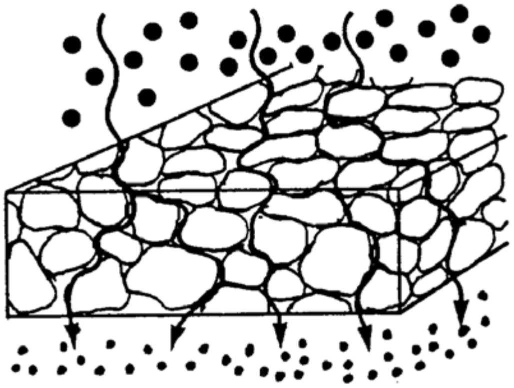
Basic Filtration Mechanisms
Fig. 1



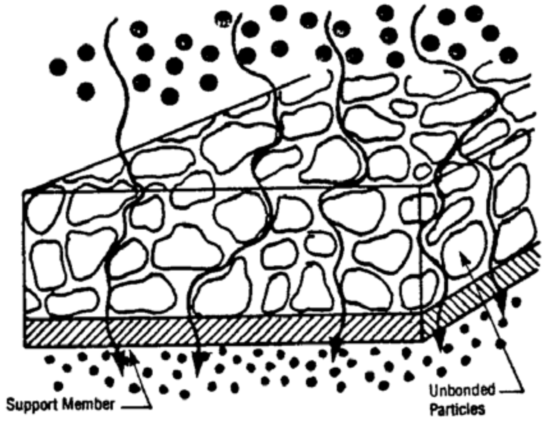
Fibrous Filter Medium
Fig. 2

2. Porous type media (See Fig. 3) are not commonly used in hydraulic applications. Porous media consists of solid or bonded particles and has flow pores and capillaries. Typical porous filter media are metals, plastics, ceramics and stone.

3. Cake-type media are comprised of a bed of loose particles formed into a cake on a supporting screen (See Fig. 4). The filter media particles are not bound together and remain loose, which makes cake-type media generally unsuitable for fluid power applications. Typical materials used are diatomaceous earth, sand, clays, wood fibers and cotton fibers.



Porous Filter Medium
(Particles Bonded Together)
Fig. 3



Cake-Type Filter Medium

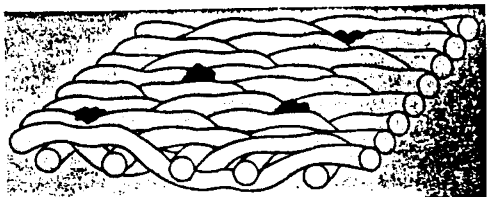
Fig. 4

Surface Filtration

Surface filtration works largely by direct interception. Adsorptive forces, although present, are weak. Surface filtration media can be classified in three types: screen, edge-type and stacked disc.

1. A screen type is essentially a two dimensional structure with a series of uniform pores through it. Generally made of metal or plastic, screens may be:

- Woven Fiber (See Fig. 5)
- Etched sheets in which the pores are produced by chemical or electrolytic processes.
- Sintered powder-thin membrane like porous media.
- Case membrane-a film of case polymeric plastic in which pores are produced by chemical leaching, photoetching, or atomic bombardment.



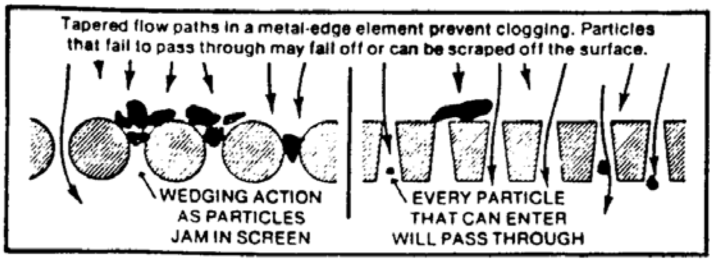
Woven Fiber Filter Medium -
Typical Dutch Twill Weave
Fig. 5

High pressure drop, high cost and low dirt capacity of membrane filters hamper their use in fluid power applications.

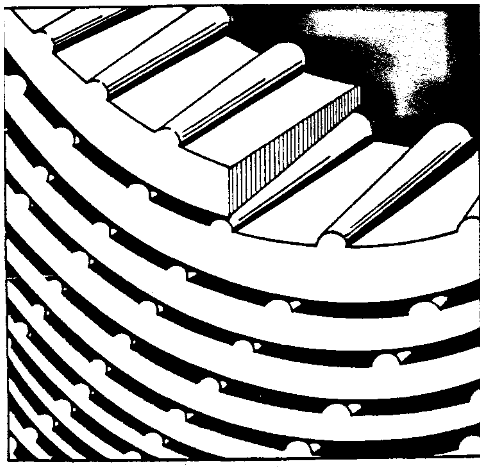
2. Edge-type media consists of a narrow ribbon or flat faced wire spirally wound with controlled spacing to provide the flow pores. Edge-type media are used mainly for macro filtration (See Fig. 6).

3. Stacked disc-type media consists of a stack of metal discs held apart by deformation or etching of the discs. The flow is radial through the spaces between the discs. Stacked disc-type media are used mainly for macro filtration. (See Fig. 7)

Edge-Type Filtration
Fig. 6



FILTER RATING AND PERFORMANCE



Stacked Disc-Type Media
Fig. 7

Filter rating is done according to a filter's ability to remove particulates of certain size levels from a fluid under specified conditions.

- **Absolute Filtration Rating**-The diameter of the largest hard spherical particle that will pass through a filter under specified test conditions. An indication of the largest opening in the filter element.
- **Nominal Filtration Rating**-An arbitrary value determined by the filter manufacturer, who may claim a nominal filtration rating based on a 90%, 95% or 98% retention by weight of a specified contaminant at a given concentration under specified conditions. Because of poor reproductability and uniformity in industry, this rating is being used less as the more exact Beta rating is becoming more widely used.
- **Beta Filtration Rating**-The Beta Ratio-The Beta ratio is defined as the number of particles of a given size upstream of a filter divided by the number of same size particles downstream under specified test conditions.

$$\beta x = \frac{\textbf{number of particles upstream}}{\textbf{number of particles downstream}}$$

X= particle size, microns

Example:

β10 = 2-- Means that the filter will remove one particle greater than 10 micron for every two particles greater than 10 micron entering the filter. Beta ratings may also be shown as: β3x=2/20/75, x=6/11/15, which means β6=2, β11=20 and β15=75. The first three numbers are the Beta ratings at the particle size of the second three numbers. Thus β11=20 means that if 20 particles, 11 microns in size enter the filter, only one will come out. β15=75 means 75 particles of 15 microns can enter, but only one will come out.

Efficiency-The ability of a filter to remove a specified contaminant at a given concentration and under specified conditions. The Beta ratio may be easily converted to an efficiency rating.

Efficiency =(1-1/I3) x 100%

The following shows efficiencies for "x" sized particles:

βx =	**1.01**	**is**	**1.0% efficient**	**βx =**	**10**	**is**	**90.00% efficient**
βx =	**1.1**	**is**	**9.0% efficient**	**βx=**	**20**	**is**	**95.00% efficient**
βx =	**1.5**	**is**	**33.3% efficient**	**βx =**	**75**	**is**	**98.66% efficient**
βx =	**2.0**	**is**	**50.0% efficient**	**βx=**	**1000**	**is**	**99.90% efficient**
βx =	**5.0**	**is**	**80.0% efficient**	**βx =**	**3000**	**is**	**99.96% efficient**

FILTER TESTS

A brief description of common tests used to rate and check performances and integrity of filter elements is as follows:

1. Bubble Point Test are performed by immersing the filter element in a liquid which thoroughly saturates the medium. Air pressure is then applied and increased until a steady stream of air bubbles appear on the outside of the filter medium and break away toward the liquid surface. The air pressure required to blow the first stream through a pore is inversely proportional to the size of the largest pore in that element. This is a nondestructive test.

2. Clean Pressure Drop Test is a nondestructive test used to evaluate the flow capabilities of a filter in the new or clean condition. Clean fluid is pumped through the system at varying flow rates at a controlled temperature. At five to seven equally spaced flow rates, the differential pressure across the filter is measured.

3. Dirt Capacity Test is a destructive test which determines the weight of a specified artificial contaminant necessary to produce a given differential pressure across a filter at specified conditions. Results are used to indicated relative service life.

4. Maximum Particle Passed Test is a destructive test used to measure the largest hard spherical particle that will pass through a filter under specified test conditions. This indicates the largest pore in the filter element (Absolute Rating).

5. Degree of Filtration Test is a destructive test used to measure the efficiency of the filter element in removing a specified contaminant at a given concentration under specified test conditions.

6. Multipass Test is a destructive test used to determine the Beta ratio of a filter element. This test was developed to simulate actual use conditions by recirculating contaminant that is not trapped by the test filter. Contaminant is also continuously fed into the system to maintain constant contamination level. Samples of the test fluid are withdrawn simultaneously upstream and downstream of the filter. These samples are then analyzed with an automatic particle counter. The resulting data may then be used to calculate the Beta ratio.

7. Cold Start Test determines the integrity of the filter element under conditions that simulate the high differential pressures generated at the startup of a fluid system, especially under cold environmental conditions.

8. Media Migration Test is a nondestructive test used to determine the amount and nature of material that a filter releases from its medium under controlled test conditions.

9. Flow Fatigue Test is a destructive test used to determine the ability of the filter element to withstand pulsating flow by cycling flow from zero to the rated flow. A bubble test is performed before and after the flow fatigue test to determine filter integrity.

10. Collapse Test is a destructive test used to determine the integrity of the filter element at high differential pressure by introducing contaminant under the rated flow until the pressure drop exceeds the required value, or until the filter element collapses.

11. Material Compatibility Test is a destructive test used to determine the ability of the filter element to withstand the service environment in which it is to be used. The element is soaked in the service fluid for not less than 72 hours at an elevated temperature. Other tests are then performed to determine element integrity; with the type of tests depending on the type of service for which the filter is intended.

12. End Load Test evaluates the axial compression to which filter elements are subjected from hydrostatic pressure and mechanical loads. After visual inspection for damage, the element is subjected to collapse test.

FILTER SELECTION

Selection of a filter element for a particular application requires consideration of service parameters such as system flow rate, operating temperature and the filtration requirement (desired cleanliness level). Also, the filter element selection process should include review of the following factors.

1. System Contaminant Sensitivity-Since each component in a hydraulic system exhibits sensitivity to various contamination particulate sizes, component sensitivity test methods have been developed. The filtration requirement of the system will depend on the most contamination sensitive system component.

2. System Contaminant Ingression-The contaminant level of a fluid system is directly related to the amount of contamination being introduced to the system. The system environment and wear rate should be considered for filter selection.

3. System Reliability-System manufacturers will usually estimate expected component service life with a specified filtration level.

4. Filter Performance and Quality-The filter suppliers should provide the necessary data on their products so that choosing the appropriate filter may be done.

FILTER COSTS

Filter cost is related to the filter rating and other performance characteristics as well as the filter location. Filter location affects costs because some system locations are critical in their structural integrity requirements. Four common filter locations are:

1. Pump Suction Line-Suction filters are limited in that they must have extremely low pressure drops. To gain this low pressure drop, suction filters have low Beta ratios and large filter medium areas. To eliminate pump cavitation, suction filters must be replaced at low differential pressure. Hence, frequent change makes this location costly.

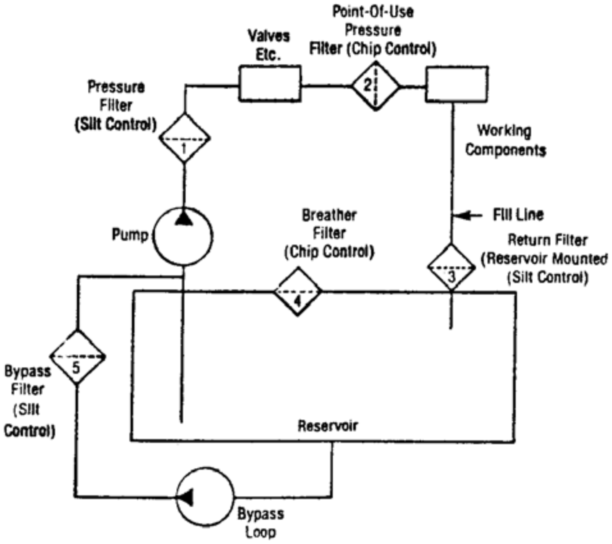
2. Pressure Line-Filters at this location are the most expensive since they must be able to withstand high differential pressures and high flow surges. These filters are used to protect contaminant sensitive components such as servo valves.

3. Return Line-The best choice if only one filter is to be used in a system. Return line filters protect the entire system and are moderate in cost. Filters at this location must be capable of withstanding high flow surges.

4. Bypass Loop-Filters at this location are lowest in cost since pressure is low, flow surge is minimal and size is moderate. A big disadvantage is the need for an additional pump which increases system cost.

The system operator should analyze the fluid sys-tem for both performance and cost, selecting filters and filter locations to arrive at the lowest cost system without sacrificing performance and protection. The best option (See Fig. 8), would be, of course, to utilize all of the above filter locations. Cost, however, often prohibits this.

A well designed, properly maintained filtration system coupled with high quality LE MONOLEC® Hydraulic Oils, MULTILEC® Industrial Oils and Low Tox® Hydraulic Oils will ensure maximum component life and system performance.



Filtration System for Fluid Power—Best Option
Fig. 8

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