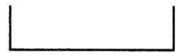
CHAPTER 15

Reservoirs, Coolers and Filters

hydraulic reservoirs

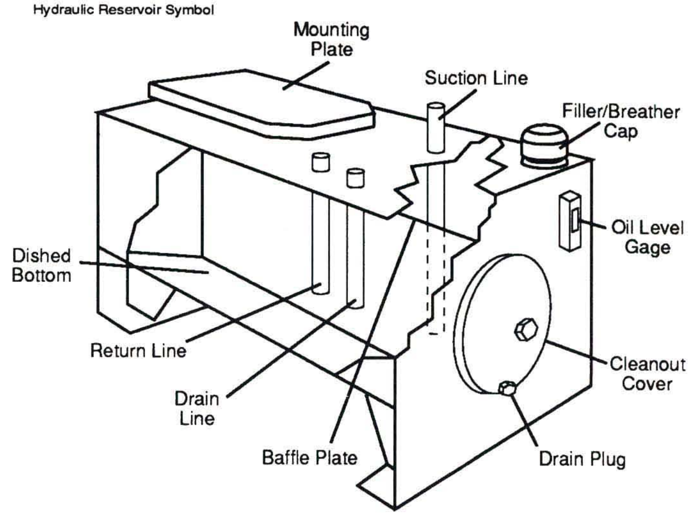
The obvious function of a hydraulic reservoir is to contain or store a system's hydraulic fluid.



Hydraulic Reservoir Symbol

what a hydraulic reservoir consists of

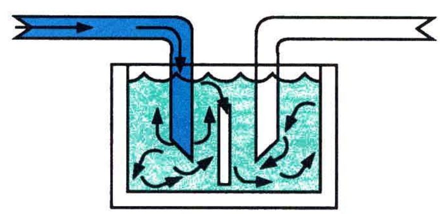
In an industrial hydraulic system, where space is not a problem and consideration can be given to good design, hydraulic reservoirs consists of four walls (usually steel); a dished bottom; a flat top with mounting plate; four legs, suction, return, and drain lines; drain plug; oil level gage; filler/breather cap; cleanout covers; and baffle plate.



how a reservoir works

Besides acting as a fluid container, a reservoir serves also to cool the fluid, to allow contamination to settle out, and to allow entrained air to escape.

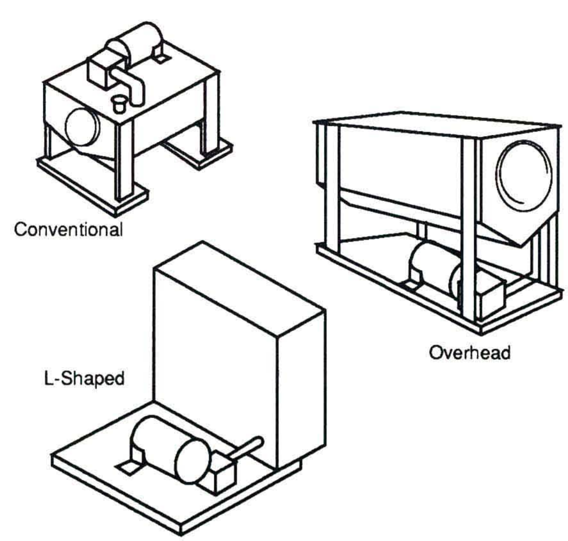
With fluid returning to a reservoir, a baffle plate blocks the returning fluid from going directly to the suction line. This creates a quiet zone which allows large dirt to settle out, air to rise to the fluid surface, and gives a chance for the heat in the fluid to be dissipated to the reservoir walls.



Fluid baffling is a very important part of proper reservoir operation. For this reason, all lines which return fluid to the reservoir should be located below fluid level and at the baffle side opposite the suction line.

reservoir types

Industrial reservoirs come in a variety of styles among which are the L-shaped reservoir, the overhead reservoir, and the conventional reservoir.

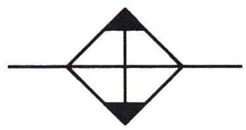


The conventional reservoir is the most commonly used industrial hydraulic reservoir.

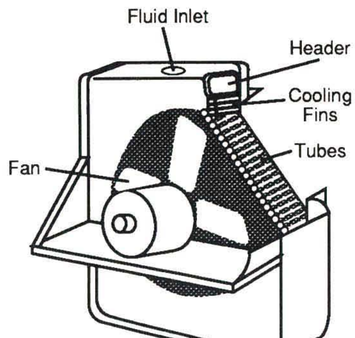
Overhead and L-shaped reservoirs afford the pump a positive head of fluid.

terms and idioms associated with reservoirs

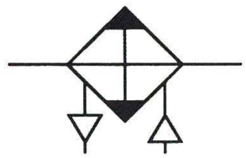
SUMP - hydraulic reservoir.



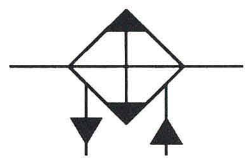
Cooler Symbol



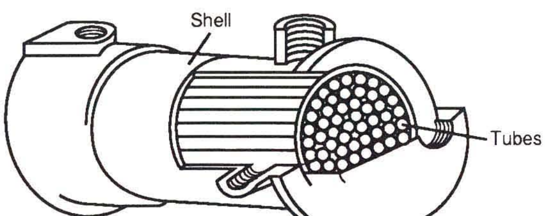
Air Cooler



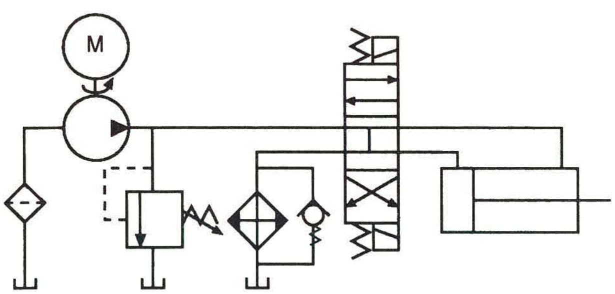
Air Cooler Symbol

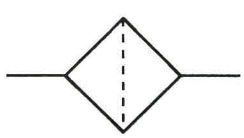


Water Cooler Symbol



Water Cooler





Filter Symbol

coolers

Inefficiency in the form of heat can be expected in all hydraulic systems. Even well designed hydraulic systems can be expected to turn some portion of its input horsepower into heat. Hydraulic reservoirs are sometimes incapable of dissipating all this heat. In these cases a cooler is used.

Coolers are divided into air coolers and water coolers.

air cooler

In an air cooler, fluid is pumped through tubes to which fins are attached. To dissipate heat, air is blown over the tubes and fins by a fan. The operation is exactly like an automobile radiator.

Air coolers are generally used where water is not readily available or too expensive.

water cooler

A water cooler basically consists of a bundle of tubes encased in a metal shell. In this cooler, a system's hydraulic fluid is usually pumped through the shell and over the tubes which are circulated with cooling water.

This cooler is also known as a shell-and-tube type heater exchanger. It is a true heat exchanger since hydraulic fluid can also be heated with this device by simply running hot water through the tubes.

coolers in a circuit

Coolers are usually rated at a relatively low operating pressure (150 psi, 10.34 bar). This requires that they be positioned in a low pressure part of a system. If this is not possible, the cooler may be installed in its own separate circulating system.

To insure that a pressure surge in a line does not damage a shell-and-tube type cooler, they are generally piped into a system in parallel with a 65 psi check valve.

Coolers can be located in a system's return line, after a relief valve, or in a case drain line of a variable volume, pressure compensated pump.

hydraulic filters

The components which have been discussed and the circuits which have been illustrated to this point will function as described and perform the job they were intended to do as long as the fluid is clean. The best designed components and the most carefully thought out circuits require clean fluid to achieve optimum performance.

All hydraulic fluids contain dirt to some degree. But, the need of a filter in a system is many times not recognized. After all, the addition of this particular component does not increase a machine's apparent actions. But, this text would be sorely lacking if it did not clearly point out that dirt in hydraulic fluid is the downfall of even the best designed hydraulic systems. As a matter of fact, experienced maintenance men agree that the great majority of component and system malfunctions is caused by particles of dirt. Dirt particles can bring huge and expensive machinery to its knees.

dirt interferes with hydraulic fluid

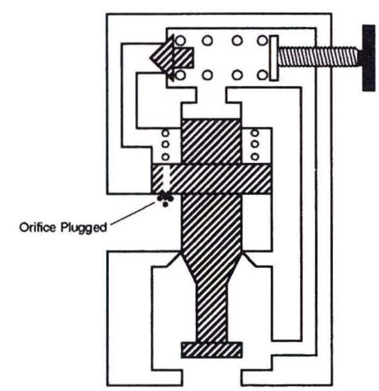
Dirt causes trouble in a hydraulic system because it interferes with the fluid which has four functions:

1. to act as a medium for energy transmission

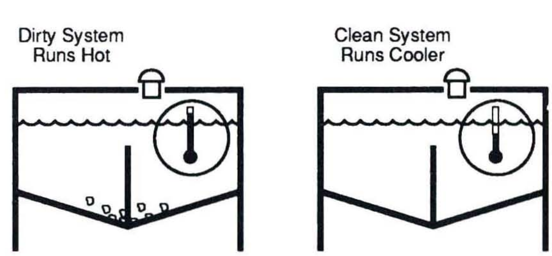
2. to lubricate internal moving parts of hydraulic components

3. to act as a heat transfer medium

4. to seal clearances between close fitting moving parts



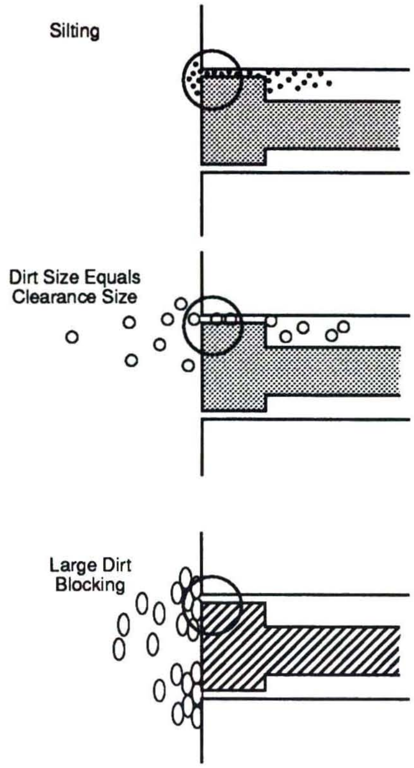
Dirt interferes with three of these functions. Dirt interferes with the transmission of energy by plugging small orifices in hydraulic components like pressure valves and flow control valves. In this condition pressure has a difficult time passing to the other side of the spool. The valve's action is not only unpredictable and non-productive, but unsafe.



Because of viscosity, friction, and changing direction, hydraulic fluid generates heat during system operation. When the liquid returns to the reservoir, it gives the heat up to the reservoir walls. Dirt particles interfere with liquid cooling by forming a sludge which makes heat transfer to reservoir walls difficult.

Clean hydraulic systems run cooler than dirty systems.

Probably the greatest problem with dirt in a hydraulic system is that it interferes with lubrication.



Dirt can be divided into three sizes with respect to a particular component's clearances; that is, dirt which is smaller than a clearance, dirt which is the same size, and dirt which is larger than a clearance.

Extremely fine dirt, which is smaller than a component's clearances, can collect in clearances especially if there are excessive amounts and the valve is not operated frequently. This blocks or obstructs lubricative flow through the passage.

An accumulation of extremely fine dirt particles in a hydraulic system is known as silting.

Dirt which is about the same size as a clearance rubs against moving parts breaking down a fluid's lubricative film.

Large dirt can also interfere with lubrication by collecting at the entrance to a clearance and blocking fluid flow between moving parts.

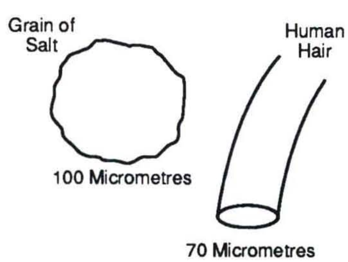
A lack of lubrication causes excessive wear, slow response, erratic operation, solenoid burn out, and early component failure.

dirt is pollution

Dirt in a hydraulic system is pollution. It is very similar to bottles, cans, paper and old tires floating in your favorite river or stream. The difference is that hydraulic system pollution is measured using a very small scale. The micrometre scale is used to measure dirt in hydraulic systems.

the micrometre scale

One micrometre (micron) is equal to one millionth of a meter or thirty-nine millionths of an inch. A single micrometre is invisible to the naked eye and is so small that to imagine it is extremely difficult. To bring the size more down to earth, some everyday objects will be measured using the micrometre scale.



An ordinary grain of table salt measures 100 micrometres (μm).

The average diameter of human hair measures 70 micrometres (μm).

Twenty-five micrometres is approximately one thousandth of an inch.

limit of visibility

The lower limit of visibility for a human eye is 40 micrometres. In other words, the average person can see dirt which measures 40 micrometres and larger. This means that just because a sample of hydraulic fluid looks clean, doesn't necessarily mean that it is clean. Much of the harmful dirt in a hydraulic system is below 40 micrometres.

40 Micrometres

determination of fluid cleanliness

Since human vision is not a proper judge, cleanliness of hydraulic fluid is determined by examining a sample of a system's fluid by visual inspection with a microscope or with the use of an automatic particle counter.

In each of these methods, the number of particles in a micrometre size range is the determining factor for cleanliness.

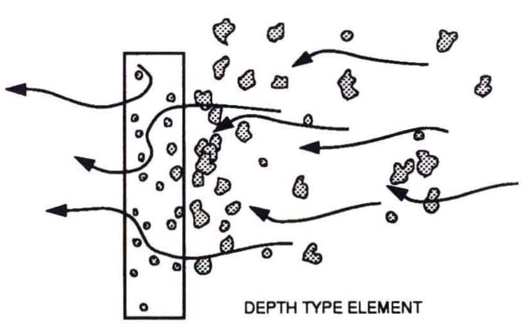
filter elements

The function of a mechanical filter is to remove dirt from hydraulic fluid. This is done by forcing the fluid stream to pass through a porous filter element which catches the dirt.

Filter elements are divided into depth and surface types.

depth type elements

Depth type elements force the fluid to pass through an appreciable thickness of many layers of material. The dirt is trapped because of the intertwining path the fluid must take.

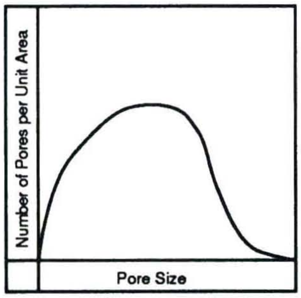


DEPTH TYPE ELEMENT

Treated paper and synthetic materials are commonly used porous media for depth elements.

pore size in depth type elements

Because of its construction, a depth type filter element has many pores of various size. This fact is shown by the pore size distribution curve.



PORE SIZE DISTRIBUTION FOR DEPTH TYPE ELEMENT

A point on the curve is the number of pores per unit area of a given size in a typical depth type element.

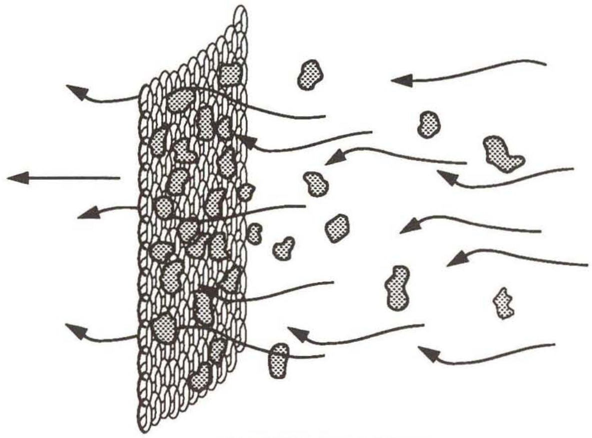
The shape of the curve shows that there are a great deal more pores of small size than of relatively large size. This means that a large percentage of flow passes through relatively small holes.

nominal rating

Since there is no one, consistent hole or pore size in a depth type element, it is given a nominal rating which is based on its average pore size.

For example, a depth element with a nominal rating of 40 micrometres means that the element's average pore size is at least 40 micrometres and that initially it will remove dirt of 40 micrometres and larger and will not remove some dirt which is smaller than 40 micrometres.

NOTE: Some manufacturers do not use an element's average pore size as a basis for a nominal rating. In these cases, the nominal rating is usually an arbitrary value which indicates little.



SURFACE TYPE ELEMENT

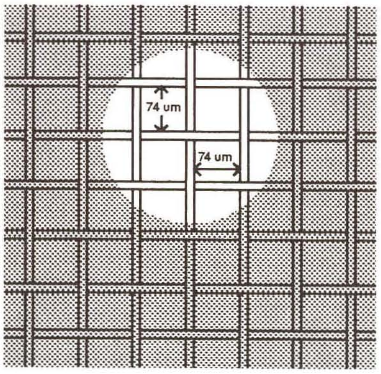
surface type elements

In a surface type filter element a fluid stream has a straight flow path through one layer of material. The dirt is caught on the surface of the element which faces the fluid flow.

Wire cloth and perforated metal are common types of materials used in surface elements.

pore size in surface type elements

Since the process used in manufacturing the cloth material and the perforated metal can be very accurately controlled, surface type elements have a consistent pore size. Because of this fact, surface type elements are usually identified by their absolute rating.

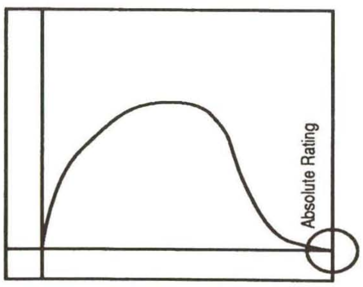


ABSOLUTE RATING
Square Wire Mesh

absolute rating

An absolute rating is an indication of the largest opening in a filter element.

This rating indicates the diameter of the largest hard spherical particle which can pass through an element.



ABSOLUTE RATING
Depth Type Element

Since the pore size can be accurately controlled in this type element, basically all the holes in a 200 wire mesh element are 74 micrometres square.

A 200 mesh wire element with an absolute rating of 74 micrometres means that for every square inch of material there are 200 wires running vertically, 200 wires running horizontally, and the perpendicular distance between the wires is 74 micrometres. Therefore, the largest, hard spherical particle to pass through the element would have a diameter of 74 micrometres.

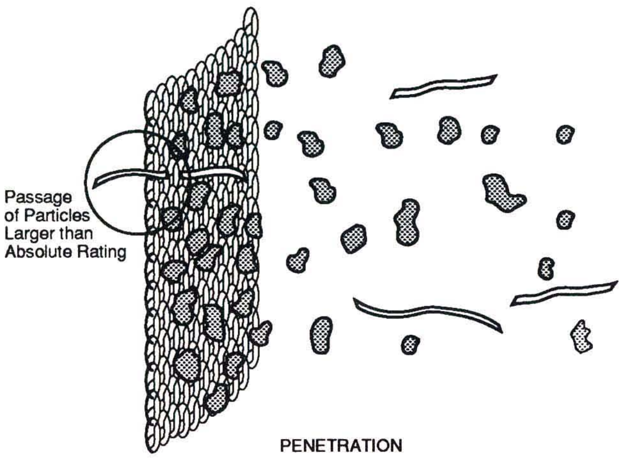
The absolute rating for a depth type element would be the last point on the pore size axis of the pore size distribution curve. There may only be one hole of that size in the element, but that would still be its absolute rating.

filter ratings in practice

As was pointed out above, an absolute rating indicates the largest hole size in an element. Sometimes, it is deduced that an absolute rating indicates the largest particle which will pass through the element while operating in a system. Since the dirt in the common hydraulic system is not spherical particles, this deduction is erroneous.

Dirt in hydraulics fluids is any insoluble material. It comes in all sizes, shapes, and materials.

An element with an absolute rating of 74 micrometres may have a difficult time catching a long, thin particle. A sliver with an overall length of 150 micrometres and a diameter of 3 micrometres, travels like a rocket in a fluid stream. The sliver penetrates the element with its 3 micrometre dimension and probes its way through the relatively large holes. Consequently, using a 74 micrometre absolute element is not a guarantee that all dirt larger than 74 micrometres will be removed from a fluid stream.



PENETRATION

An absolute or nominal rating only indicates a filter element's largest or average hole size. Filter ratings do not guarantee what size particles will be removed or how clean a fluid will become.

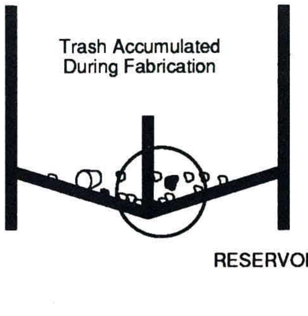
To determine how fine and what type of a filter element should be used to protect a specific hydraulic component, consult the component manufacturer or a reputable filter dealer.

sources of dirt

Dirt was previously defined as any type of insoluble material in a hydraulic fluid. Dirt comes in all sizes, shapes, and materials and has several sources by which it enters a system.

dirt built into a system

Hydraulic systems which are newly fabricated are often extremely dirty. As a machine is being assembled, the reservoir becomes a collection point for rust, paint chips, dust, cigarette butts, grit and paper cups. Even though the reservoir is "cleaned" before it is filled with fluid, a sample of the fluid taken shortly after start up time will show

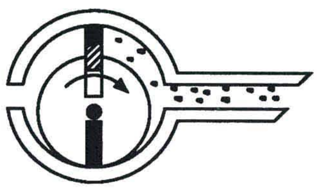


RESERVOIR

dirt particles of many foreign materials. Many dirt particles which are harmful to a system are invisible to the naked eye and cannot be removed by wiping with a rag or blowing off with an air hose.

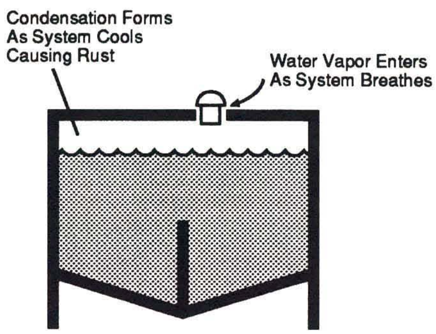
The components which make up a new system may also be sources of system contamination. Because of storage, handling, and installation practices, new directional valves, cylinders, relief valves, and pumps may be equipped with dirt particles which enter a fluid stream after a very short time.

dirt generated within a system



Pump Generating Dirt

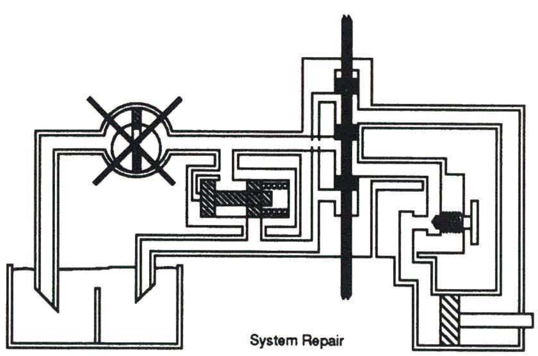
Another source of dirt is the dirt generated within the system itself. As a machine continues to operate, moving parts naturally begin to wear and generate dirt. Every internal moving part in a system can be considered a source of contamination for the entire system.



Component housings are continuously flexing from normal stresses and are constantly subjected to hydraulic shock pressures. These actions cause metal and casting sand to break loose from the housing and enter the fluid stream.

Air entering the reservoir during operation contains water vapor. When the machine is shut down, the air inside the tank cools and water vapor condenses on the walls. This causes the formation of rust which eventually is washed into the fluid.

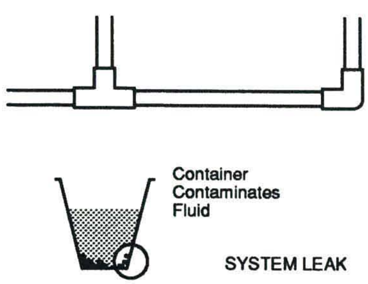
dirt added to a system



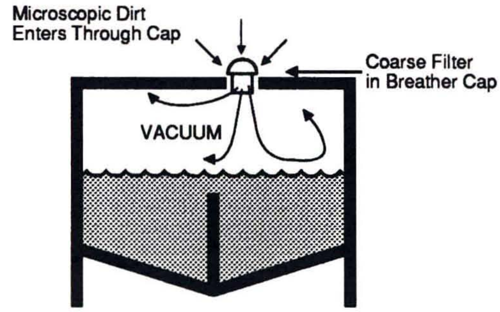
An additional source of dirt is the dirt added to a system. This is many times the result of ordinary maintenance practices or a lack of maintenance.

If a pump happens to break down, the maintenance man replaces the component or repairs it right on the spot. In either case he will be working in a dirty environment, which will contaminate the system as soon as a line is cracked.

If the pump is disassembled, more than likely it will be done on a dirty workbench and the parts will be wiped off with a "not-too-dirty" rag before reassembly. When the pump is replaced, it will spread dirt throughout the system.



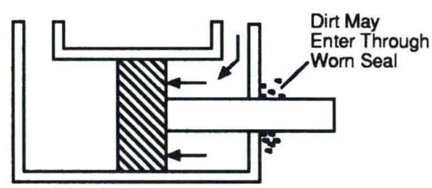
The usual first aid measure for a line which has sprung a leak is to put the nearest "clean" bucket under the leak. After it is repaired, the maintenance man must dump the bucket of fluid. It usually happens if no convenient way is seen to dispose of the contaminated fluid, it is poured back into the reservoir. It was one bucket short any way.



SYSTEM BREATHER

The atmosphere in which the machine lives contaminates a system's hydraulic fluid. Operation of a hydraulic system depends upon air entering the reservoir through the breather cap and pushing the fluid up to the pump. As actuators in the system are filled and discharged with fluid, the tank actually inhales and exhales dirt-laden air which is filtered by a coarse screen in the breather cap. The dirt which is not filtered out settles into the fluid.

Breather caps are very rarely, if ever, cleaned. Because of this lack of maintenance, the screen becomes plugged. As a result, the breather cap is removed from the reservoir or the atmosphere finds a path through an old, cracked seal or stripped bolt hole. Now a clear path to the fluid is open for almost anything.



Dirt can also be added to a system by means of a cylinder. After a time, a cylinder's rod wiper seal wears. In this condition, dirt is drawn into the system each time the cylinder rod retracts.

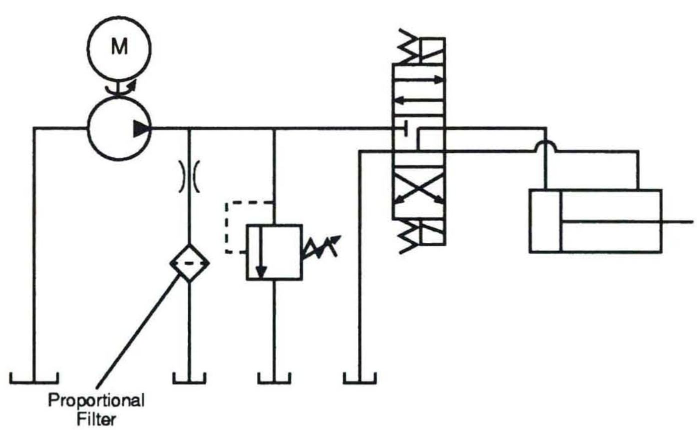
type of filtration by flow

In the early days of hydraulics, filtration was not considered necessary, and this was more or less a correct assumption. Hydraulic components at that time were crude when compared to modern standards. Clearances between moving parts were large, therefore dirty fluid would not affect operation that much. Components were dirt tolerant to a large extent.

As manufacturing processes naturally improved, tolerances were improved. Component operation became much more efficient, but components were less dirt tolerant. The need for filtration was recognized.

proportional flow filtration

The first measure was to place a filter in a system in such a way that a part of the total volume of a pump was filtered. This can be done by placing a filter in a system so that a portion of a pump's flow is bled off through the filter.



full flow filtration

Proportional flow filtration was found to be inadequate after a time, especially as system components became more and more efficient.

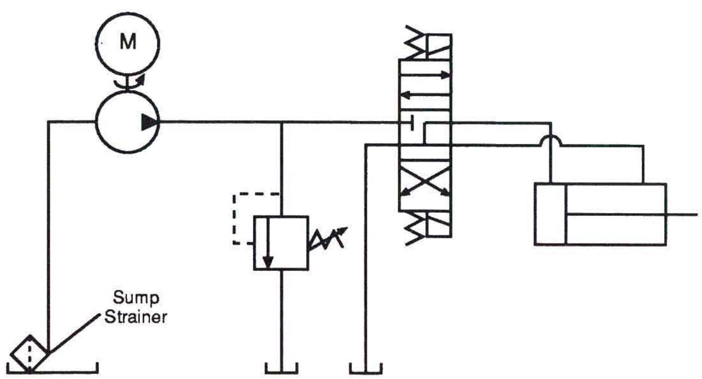
The next step was to place a filter in a system so that all flow from a pump was filtered.

This full flow filtration is the type of filtration used in most modern hydraulic systems.

type of filtration by position in a system

A filter is protection for a hydraulic component. Ideally each system component should be equipped with its own filter, but this is economically impractical in most cases. To obtain best results, the usual practice is to strategically place filters in a system.

In the majority of applications the fluid reservoir is a large source of dirt for a system. Since a pump is the heart of a system, one of the most expensive components in a system, and one of the fastest moving system components, it seems logical that a good place to put a filter is between a reservoir and pump.



sump strainer

A sump strainer is usually a coarse filter element screwed onto the end of a pump's suction line.

The range of filtration for sump strainers is a perforated metal cylinder with large drilled holes to 74 micrometre wire mesh.

Advantages:

1. Sump strainers protect the pump from dirt in the reservoir.

2. Because they have no filter housing, sump strainers are very inexpensive.

Disadvantages:

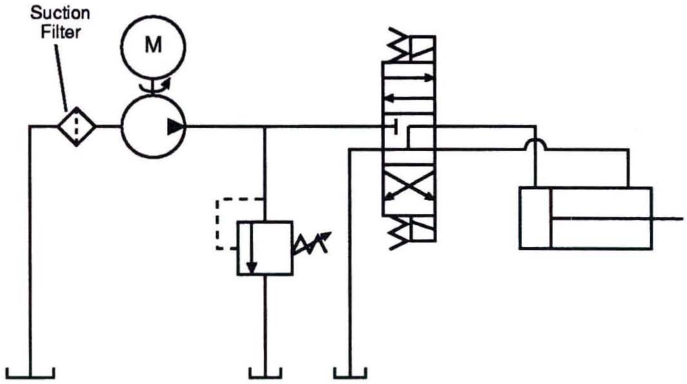
1. Being below fluid level, sump strainers are very difficult to service when cleaning is necessary, especially if the fluid is hot.

2. A sump strainer does not have an indicator to tell when it is dirty.

3. A sump strainer may block fluid flow and starve the pump if not sized correctly and properly maintained.

4. A sump strainer does not protect components downstream from the particles generated by the pump.

suction filter



A suction filter is placed in the suction line outside of the reservoir. Range of filtration usually found in suction line filters is from 238-25 micrometres.

Advantages:

1. A suction filter protects the pump from dirt in the reservoir.

2. Since the suction filter is outside the reservoir, an indicator telling when the element is dirty can be used.

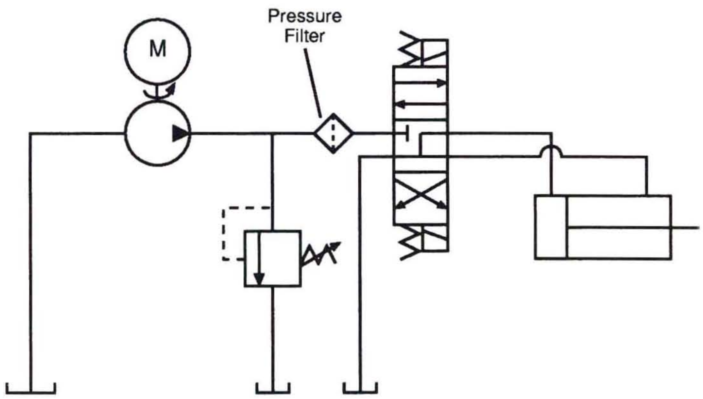
3. The filter element can be serviced without disassembling the suction line or reservoir.

Disadvantages:

1. A suction filter may starve the pump if not sized or engineered into the system properly.

2. A suction filter does not protect components downstream from the particles generated by the pump.

pressure filter



A pressure filter is positioned in the circuit between the pump and a system component.

Range of filtration usually found in pressure line filters is from 40-3 micrometres.

A pressure filter can also be positioned between system components. If the flow between the components can flow in two directions (as between directional valve and cylinder), the filter must be capable of handling bidirectional flow. Bidirectional pressure filters are used on the downstream side of servo valves and in closed looped hydrostatic transmissions.

Advantages:

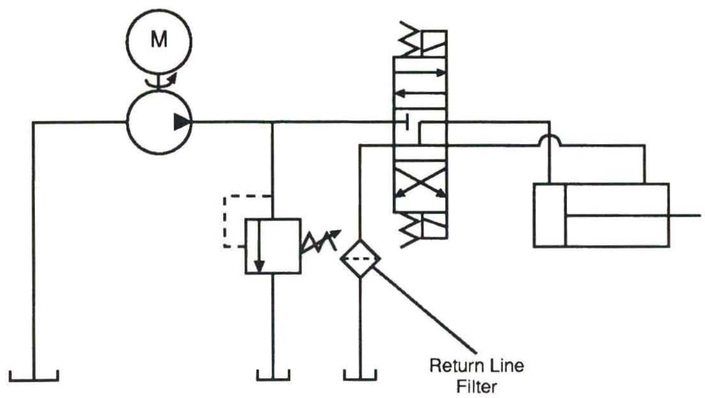
1. A pressure filter can filter very fine since system pressure is available to push the fluid through the element.

2. A pressure filter can protect a specific component from the harm of deteriorating particles generated from an upstream component.

Disadvantages:

1. The housing of a pressure filter must be designed for high pressure because it is operating at full system pressure. This makes the filter expensive.

2. If pressure differential and fluid velocity are high enough, dirt can be pushed through the element or the element may tear or collapse.



return line filter

A return line filter is positioned in the circuit just before the reservoir. Range of filtration usually found in return line filters is from 40-5 micrometres.

Advantages:

1. A return line filter catches the dirt in the system before it enters the reservoir.

2. The filter housing does not operate under full system pressure and is therefore less expensive than a pressure filter.

3. Fluid can be filtered fine since system pressure is available to push the fluid through the element.

Disadvantages:

1. There is no direct protection for circuit components.

2. In return line full flow filters, flow surges from discharging cylinders, actuators, and accumulators must be considered when sizing.

3. Some system components may be affected by the back pressure generated by a return line filter.

filter bypass valve

If filter maintenance is not performed, pressure differential across a filter element will increase.

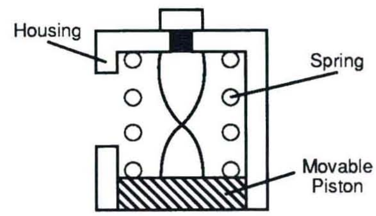
An unlimited increase in pressure differential across a filter on the suction side of a system means that a pump will eventually cavitate.

An unlimited increase in pressure differential across a filter on the pressure side means that the filter element will eventually collapse.

To avoid this situation a simple or direct acting relief valve is used to limit the pressure differential across a full flow filter. This type relief valve is generally called a bypass valve.

what a bypass valve consists of

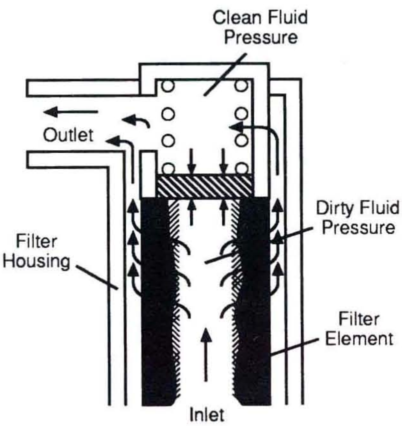
A bypass valve basically consists of a movable piston, housing, and a spring which biases the piston.



how a bypass valve works

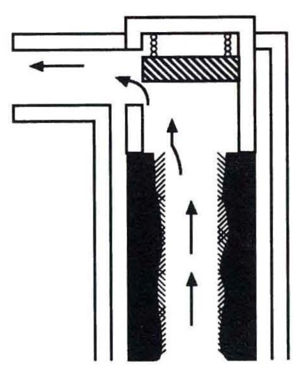
There are several types of bypass valves, but they all operate by sensing the difference in pressure between dirty and clean fluid.

In our illustration, pressure of dirty fluid coming into the filter is sensed at the bottom of the piston. Pressure of the fluid after it has passed through the filter element is sensed at the other side of the piston on which the spring is acting.



As the filter element collects dirt, the pressure required to push the dirty fluid through the element increases. Fluid pressure after it passes through the element remains the same. When the pressure differential across the filter element, as well as across the piston, is large enough to overcome the force of the spring, the piston will move up and offer the fluid a path around the element.

A bypass valve is a fail safe device. In a suction filter, a bypass limits the maximum pressure differential across the filter if it is not cleaned. This protects the pump. If a pressure or return line filter is not cleaned, a bypass will limit the maximum pressure differential so that dirt is not pushed through the element or that the element is not collapsed. In this way, the bypass protects the filter.

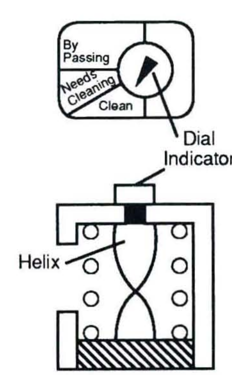


Dirty Fluid Bypassing

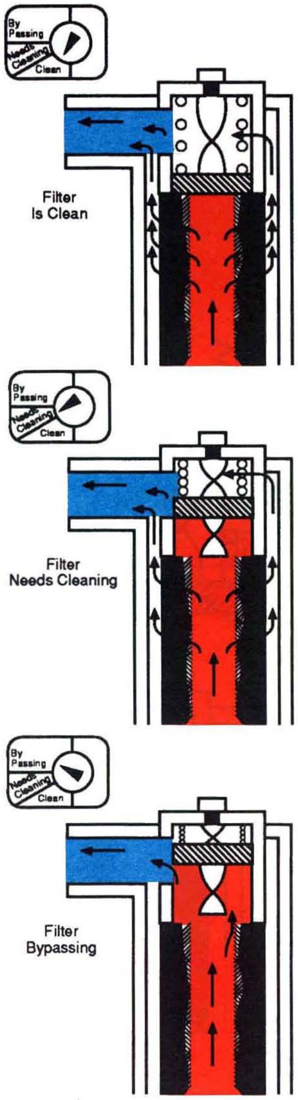
The whole key, then, to filter performance centers around cleaning the filter when it needs cleaning. To help in this regard, a filter is equipped with an indicator.

filter indicator

A filter indicator shows the condition of a filter element. It indicates when the element is clean, needs cleaning, or in the bypassing condition.



Filter Indicator



what a filter indicator consists of

One common type of filter indicator consists of a helix and a dial indicator which is attached to the helix.

how a filter indicator works

The operation of a filter indicator is dependent on the movement of the bypass piston. When the element is clean, the bypass piston is fully seated and the indicator shows "clean."

While pressure differential across the piston and element increases to the point where the filter needs cleaning, the piston moves up. During its movement, the piston twists the helix which positions the indicator dial at "needs cleaning."

If the filter element is not cleaned when indicated, pressure differential will continue to increase. The piston will continue to move up and bypass the fluid. At this time the indicator will show a bypassing condition.

filters must be maintained

A machine may be equipped with the best filters available and they may be positioned in the system where they do the most good; but, if the filters are not taken care of and cleaned when dirty, the money spent for the filters and their installation has been wasted. A filter which gets dirty after one day of service and is cleaned 29 days later gives 29 days of non-filtered fluid. A filter can be no better than the maintenance afforded it.

exercise
reservoirs, coolers, filters
48 points

INSTRUCTIONS: Find a word in column 2 related to a word in column 1. Then, pair up two more words which have the same relationship, taking one from column 3 and one from column 4. For example: bird-air & fish-water. All words are used once.

1	2	3	4
Filler/breather			
VI improver			
Depth element			
40% water-60% oil			
Nominal			
Water available			
Dirt built-in			
Pressure filter			
Bird	**Air**	**Fish**	**Water**

invert emulsion	**5% oil-95% water**	**AW**
synthetic	**absolute**	**air cooler**
EP	**water scarce**	**reservoir**
cleanout cover	**R & O**	**pump**
directional valve	**suction filter**	**wire mesh**
average	**oil-level gage**	**baffle**
new components	**surface element**	**largest**
shell-and-tube cooler	**dirt added**	**soluble**