

# Hydraulic & Lubrication Filters

## Part II: Proper Filter Sizing

Every filter has a minimum of two components. They are the filter housing and filter element. Most filters include an integral bypass valve. This valve provides a parallel flow path to a filter element to protect it from collapsing, during cold start or once the element is heavily loaded with contaminant, by maintaining a desirable differential pressure across the element. For most part we want the flow to go through the filter element and thus the bypass valve is biased with a compression spring. The force of this spring keeps the bypass valve closed and for the most part fluid flows through the element. However, as element gets dirty by collecting contaminants, the pressure drop across reaches the setting of the bypass valve at which time there are two paths for the fluid. At some point and time, the bypass valve may allow 95% of fluid to go through it. Bypass valves have a cracking pressures typically range between 1,77 BAR (25 PSID) and 7 BAR (102 PSID). It is dependent upon the location of a filter. Return line filters have a lower setting than the filters in the pressure line.

Generally, the sizing of filter is very simple. This paper will make it even simpler for you. One must be careful as the filter will only perform adequately if it is maintained properly. It is a very good practice to change the filter immediately when the differential pressure indicator signals the need for service. Differential pressure indicators should signal at 90% pressure drop of the bypass setting. An alternative to changing on indication is a preventive maintenance schedule. For example the elements may be changed on a time interval regardless of element condition. This will ensure that the filter will not consistently operating in a bypass condition.

### 1. MAXIMUM FLOW RATE THROUGH A FILTER

Maximum flow through a filter may be larger than the maximum flow from the pump. This happens due to presence of double acting hydraulic cylinders in a system. If your system contains such cylinders, you must calculate the maximum flow rate from the blind end of the cylinder and size the filter accordingly. This applies to return line filters.

### 2. MAXIMUM SYSTEM PRESSURE

Generally this depends upon the location of the filter. Pressure line filters usually see the full pressure setting of the relief valve. Whereas the return line filter may see no more than 100 PSI pressure. An appropriately rated filter will serve the purpose. Occasionally a filter will experience pressure fluctuations and in such cases, fatigue rating of the filter housing must be considered. It is wise to consult your filter supplier for guidance in such conditions as the rated fatigue pressure is typically lower than the maximum rated operating pressure of a given filter.

### 3. MINIMUM & OPERATING FLUID TEMPERATURE (VISCOSITY)

Viscosity of most hydraulic fluids varies inversely with the temperature. The lower the temperature the higher the viscosity and vice-versa. During “cold start up” the viscosity of the fluid may be high enough to cause a very high pressure drop through the element. It will open up the bypass valve for a short time while the fluid is being warmed up. In most cases, this condition is OK. See **Footnote** at the end for an explanation.

The fluid temperature also has an effect on seals. Select seals that will withstand extreme temperature without failure.

### 4. ACCEPTABLE PRESSURE DROP

Do not consider the pressure drop of the housing and clean element in your system design. It is the best condition that the system will ever see. Always consider the worst case. It will occur when the entire flow goes over the bypass valve. It is imperative that you consider the maximum pressure drop across the bypass valve at the maximum flow. For example, if a filter has a 40 PSID bypass valve, then it is likely that at the maximum flow this valve may have a pressure drop of 5 BAR (70 PSID) or higher. Ask for this information from your filter supplier and use it in your calculations. If you locate a filter in a return line and the full flow bypass valve pressure drop were to be 5 BAR (70 PSID) or higher then you must make sure all the components upstream of filter will not be affected. Shaft seals of a hydraulic motor have been known to fail due to excessive back pressure caused by a filter.

### 5. FILTER ELEMENT SERVICE INTERVAL

This is one of the most difficult criteria for filter selection, and in most cases it is based upon the design engineer's experience with a similar system. When an engineer selects a filter for a new machine or even an existing application, various manufacturers may give him data. Typical data include maximum flow rate, maximum pressure drop at a certain viscosity, Beta ratio (Filtration ratio) and dirt holding capacity. The last two values are obtained from Multipass test Method per ISO 16889. The engineer must select an element with highest capacity all other things being equal. This will give him the maximum life between element changes in a given system.

Sometimes, an engineer may select a slightly larger filter to increase the filter element change interval. There is no right or wrong answer but under sizing a filter to save money is wrong in the long run. A smaller filter will be less expensive in the beginning but the downtime it may cause due to frequent changes will reflect in poor productivity and throughput.

In a critical system, size a filter such that it gives you maximum life. General rule of thumb is to change an element when the differential pressure indicates the need for a change or based on a preventive maintenance schedule that can coincide with a planned shutdown regardless of the element condition.



## FILTER ELEMENT SERVICE INTERVAL CONTINUED

For simple calculation to determine element life in PSID, use following formula:

EL = BYPASS SETTING IN PSID – (H + E) where,

EL is element life in PSID

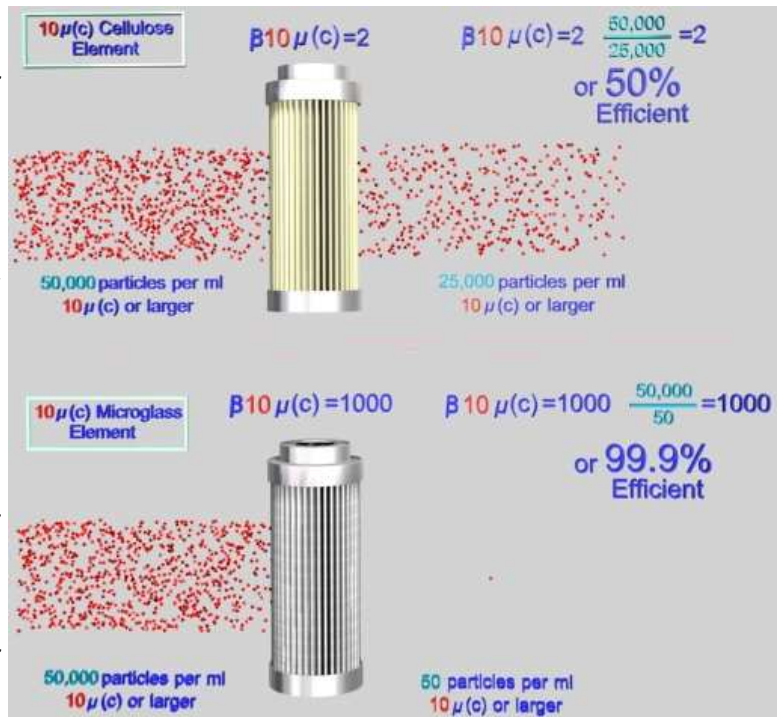
H is housing pressure drop in PSID

E is the clean element pressure drop at a flow and viscosity of interest.

A minimum rule of thumb is to allow 1 BAR (~15 PSID) life for a normal hydraulic system and for critical system, 1.7 BAR (~25 PSID). Selecting a larger filter will allow the element to last longer as the clean element pressured drop will be lower. Element life is defined by the amount of time, or contaminant, that the element will see before the indicator signals. Using a larger filter will yield a lower flow density through the element. Lower flow density means a lower flow rate per  $\text{cm}^2$  ( $\text{IN}^2$ ) which means that the element pressure drop will rise at a slower rate as it loads with contaminant.

## 6. FILTER MEDIA SELECTION

There are several distinct differences between available media options. Media selection should be based upon the required cleanliness and other unique needs of the system. Evaluate the Beta ratio (efficiency), dirt holding capacity, flow versus pressure drop characteristics, etc. A filter supplier should be able to supply more detailed test information in addition to what is supplied in the literature. Normally, wire mesh and cellulose media elements are nominally rated which means that they might be only 50% efficient at the rated micron size. Most glass media elements are considered to be “absolute” rated which means that they are 99.5% efficient at the rated micron size. Check the Beta ratio before selecting the media as all “10 micron” filter elements do not filter with the same efficiency. Absolute rated high efficiency glass media elements are the most suitable selection for achieving target ISO cleanliness codes on systems with components that are sensitive to contamination (servo valves, piston pumps, etc). Consult component manufacturers for required fluid cleanliness as this can be directly correlated to warranty requirements. Filter suppliers can also be a valuable resource for determining overall system cleanliness guidelines.



## FILTER MEDIA SELECTION CONTINUED

The majority of filter elements today are designed to be disposable, and utilize media constructed of synthetic or organic fibers. These elements are non cleanable and must be disposed off after their useful life. Some applications are fitted with stainless steel wire mesh media elements that yield a very low pressure drop and are somewhat cleanable. After they become loaded with contaminant they can be removed from the housing, cleaned and put back in the system. It is important to note that the cleaning process may be destructive which can compromise the element's efficiency and integrity (ultrasonic cleaning, high pressure steam cleaning). Cleanable elements typically have a shorter life than their disposable counterparts made of glass or cellulose media, size for size. Wire mesh media elements are typically applied on systems with high viscosity fluids that do not require ultra clean fluid (gear box pressure line in steel mill).

### 7. FILTER ELEMENT COLLAPSE-BURST RATING

The full flow pressure drop through a bypass valve should be less than the collapse pressure (for outside to in flow) or burst pressure (for inside to outside flow) of the element. The element collapse/burst pressure should at least be 1.5 times the full flow pressure drop across the bypass valve. This will provide ample protection from collapse or burst even if there was a sudden increase in flow due to surge.

Applying an element with insufficient strength can result in a fully loaded element failing and releasing all of the previously captured contaminant along with filter element materials into the system. This sudden release of contaminant will surely cause catastrophic failure.

### 8. FLUID TYPE, PETROLEUM vs. SYNTHETIC

Petroleum base fluids have specific gravity of 0.86. Filters are generally sized for petroleum fluid in a hydraulic or lube system. Occasionally synthetic fluids are used in hydraulic system, such as water glycol or high water based fluid. High water based fluids are constructed of 95% to 98% water with additive package to provide lubricity, biocide, etc. Always consider the effect of specific gravity on pressure drop. Most filter manufacturers will provide recommendations for sizing a filter for use such fluids. Another issue with synthetic fluids is their compatibility with seals. Select the proper seal material as recommended by the fluid manufacturers.

Synthetic fluids can be highly corrosive (phosphate ester). Filter housings and element components may require special treatment or the use of stainless steel. It has also been proven that aggressive fluids can attack binding chemicals in non-woven filter media. Some synthetic fluids (fire resistant) can develop elevated acid levels (TAN) which can damage the filter media causing media migration and loss of efficiency. Contact Hy-Pro when synthetic fluids are used to ensure proper material selection.

Certain high water based fluids have a very high pH value to keep growth of bacterial low. These fluids can react aggressively with aluminum parts in housing. For such applications, either avoid aluminum or anodize aluminum parts for added protection. Water glycol emulsions can fluctuate. It is wise to over size the filter assembly to avoid high differential pressure in the event that the emulsion yields higher than normal viscosity.



## 9. OVER SIZING FOR FUTURE FLEXIBILITY

Once a filter has been selected and sized it is important to consider using a filter that is larger to allow for unforeseen system changes in the future. One of the key parameters mentioned earlier relates to fluid viscosity. If the selected filter is just large enough to handle the current system a change in fluid to a higher viscosity could result in an unacceptable element life. Improving fluid cleanliness typically results in exponentially longer bearing and hydraulic component life. A common strategy for achieving lower ISO cleanliness codes ( $4\mu_{[c]}$ / $6\mu_{[c]}$ / $14\mu_{[c]}$ ) is installing filter elements with a finer degree of filtration. If the filter housing is not large enough this might not be possible as the pressure drop can be prohibitive. Over sizing the filter ahead of time will allow finer filter elements to be used in the future. The alternative is to install a new larger filter housing that might have a larger port to port dimension which will require additional pipe fitting.

### Footnote:

On occasion the fluid in the system will be very cold (high viscosity). Under such conditions the fluid may bypass the element until the fluid temperature rises. Typically downtime before start up is less than 24 to 48 hours. When the system is shut down due to end of a task or end of a shift, it is very likely that the oil in the system is clean to acceptable standards. Upon start up the oil is still clean and stays clean until it warms up.

We recommend that filter be sized for normal operating conditions and not for cold start ups. However, there are applications where bypass is not acceptable. In this case the filter must be sized for the worst condition. Such a filter will generally be large and should be fitted with a high collapse element and no bypass.

### Conclusion:

Filters are frequently considered as a necessary evil and are added to a system as an after thought instead of a valuable asset. Proper filter selection and sizing can provide years of reliable equipment operation and save money that is commonly lost battling contamination related failures. Approximately 75% of all hydraulic component failures are attributed to surface degradation caused by contamination and corrosion. The cost of installing and maintaining suitable filtration is estimated to be 3% of the cost associated with contamination related issues, the tip of the iceberg. Hidden costs of runaway contamination include; unplanned downtime, component replacement or repair expenses, fluid replacement, disposal, maintenance labor hours, troubleshooting time and energy, and waste.

