What is Oil Filtration

By Dennis Morgan, Filtration Consultant and President of AMS Filtration
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This is a seemingly simple question with seemingly simple answers. The problem however is because so many different products exist in the marketplace, either confusion abounds or there is an attempt to oversimplify in order to cut through the confusion.

The answer to the question is simple enough – filtration is using some method to remove suspended contamination from oil for either the protection of equipment (screening) or extending the life of the oil (cleaning). The solutions to oil filtration are not so simple and that's where the confusion begins.

First there are two types of oil filtration – PRIMARY oil filtration (screening) and SECONDARY filtration (cleaning). The two types of oil filtration serve two very different purposes and are very different as a result.

Primary filtration is designed for equipment protection and is usually installed by the original equipment manufacturer. This type of filtration is almost always full flow with a bypass valve and is designed to keep out large particle contamination (many times 25 micron and larger). This is why it is referred to as oil screening. Its purpose is not to keep the oil clean at very low ISO cleanliness levels but to keep large particles from damaging the lubricated equipment. Generally , primary filtration will be installed in the equipment lubrication circuit, either in the pressure line going out to the lubrication point(s) or the return line from the lubrication point(s). Because of this, primary filtration cannot be constructed in such a way to restrict flow to a level that would deny the equipment proper lubrication. The philosophy is that dirty oil is better than no oil and many times, dirty oil is exactly what the equipment receives. The filter media is generally very porous and when the media becomes blocked with contamination, the internal bypass valve will open allowing unfiltered oil to exit the filter and reach the equipment.

Secondary filtration is designed for extending the life of the oil by cleaning it. This is also referred to as oil purification. The advantage of oil purification is not only extending the life of the oil, but also extending the life of the equipment with clean oil. There are several methods of oil purification, too numerous to address in this article. Sometimes original equipment manufacturers will include secondary filtration but rarely. Generally secondary filtration will be an add on aftermarket system and will be an off-line, side stream or kidney loop configuration. Secondary filtration will also usually clean oil down to very low ISO cleanliness levels that primary filtration cannot. Some examples of oil cleaning or purification are centrifugal, magnetic, vacuum dehydration, depth filter media or full flow filter media

Primary filtration is important and with very rare exceptions, OEM filtration should not be altered. Secondary filtration can add great benefit to the equipment owner by extending the life of the oil in the system and the equipment. Primary filtration will help protect the equipment investment whereas secondary filtration helps to maximize the return on the equipment investment and maximize the return on the oil investment. With the continued rise in equipment costs, down time costs and oil replacement costs, adding secondary filtration to equipment can be a very smart decision for the equipment owner.

Full Flow versus Depth Filtration

Although there are many different options in the marketplace for use as secondary filtration, the most common methods are either an add on full flow filter system or an add on depth filter system. These systems will be installed outside the equipment lubrication circuit as an off-line, side stream or kidney loop configuration. Both full flow and depth filtration flow oil through a filter media to remove the contamination, but how the oil flows is very different.

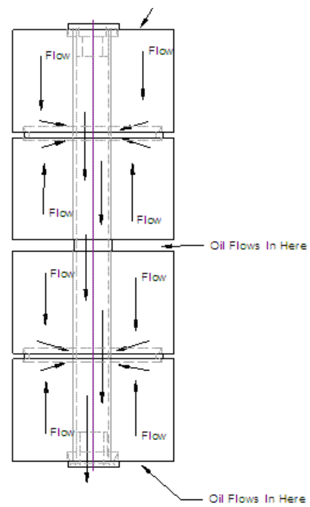
In Full Flow (or Pass Through) filtration, the oil flows directly through the filter media. This type of filter will be pleated and is the type of filter element most people are familiar with. Full flow filters act to stop contamination by only allowing particles smaller than the pore size (gaps in the media) to pass through. Because of the pass through nature of this type of filter, pleated full flow filters have a very short flow path through the media.

There are two common types of media used for full flow filters, pleated cellulose and pleated micro-fiberglass. Cellulose is a natural fiber media that is inexpensive and provides a moderate level of filtration efficiency. Micro-fiberglass is a synthetic media that provides a much higher level of filtration efficiency than pleated cellulose. Both types of media can handle high flow rates, are useful for high viscosity oils (ISO680) and are usually safe for special oil additive packages that may be diminished by use of depth filtration.

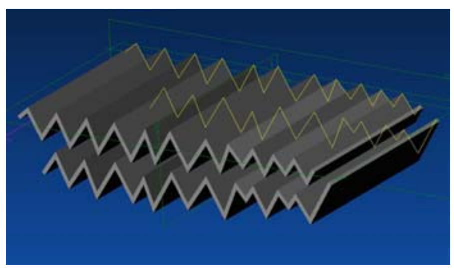
Depth filtration however, has a long flow path, as much as 9 inches. There are two types of depth filtration, direct flow or axial flow. Direct flow is similar to pass through full flow except the path of flow is much longer (usually several inches) and the flow rate is restricted by the longer flow path.

Axial Flow Depth Filtration uses rolls of media (see photo to the left) and the oil does not flow through the media, but rather along the layers of the roll of media. The media is generally high strength cellulose paper that has been creped before rolling. This type of media allows for cleaning the oil at a low ISO Cleanliness level, removal of free and dissolved water and is relatively inexpensive. There is far more media in Axial Flow Depth elements than most other types and thus are able to hold large amounts of solid contamination and water. The element to the left has 8 pounds of paper media in the rolls and will hold up to 10 pounds of solid contamination and up to 1 gallon of water.

While the elements are being constructed and the paper is being rolled, it is stretched slightly to allow the creping to open wider than its normal amount. As the paper gets rolled layer upon layer, the creping goes back to its relaxed state creating an interlocking of the layers in the roll. This is important because as the oil flows between the layers of paper, the interlocked creping form a jagged flow path to help dislodge the contamination from the oil.



Axial flow depth elements do not have a bypass valve so NO unfiltered oil can ever leave the element. Because of this, they must be installed in systems that have a relief valve before the filter, such as an internal relief valve in a gear pump.



Both full flow and depth filtration have their advantages and disadvantages. The chart below illustrates some of the pros and cons of each type of media.

	Pro	**Con**
Cellulose Depth Media	■Very Low Cleanliness Levels ■Relatively Inexpensive for the Efficiency ■High Contamination Capacity (About 10 lbs of Solids) ■Absorbs Water (About 1 Gallon)	■Low Flow Rate ■Not for ISO 680 or Higher ■Not for LE Duolec™ Oils
Micro-Glass Full Flow Media	■Reasonably Low Cleanliness Levels ■Higher Flow Rates (Up To 300 gpm) ■Useful for High Viscosity Oils ■Can Safely be used with LE Duolec™ Oils	■Higher cost than Cellulose Depth Media ■Holds less Solid Contamination than Depth Media ■Does NOT Absorb Water

Ultimately, the decision about secondary filtration will be made by looking at all the factors involved and choosing a method that best fits situation. Filtration, is like most other industry, does not have a one size fits all solution. There are many factors to be considered when choosing and sometimes tradeoffs have to be taken into consideration. For example, Lubrication Engineers Duolec™ oils should not be filtered with depth media filtration (due to the medias' effectiveness in removing some forms of additive chemistry) so Micro-Glass is the obvious choice. However, if water contamination is a problem in a Duolec™ application, the Micro-Glass will not remove the water. Depending on the severity of water contamination, another oil purification option may need to be considered in addition to Micro-Glass filtration to get the Duolec™ as clean as desired.

What Kind of Filtration to Choose?

The filtration marketplace is filled with a multitude of choices for purifying oil. Often this multitude of choices can be mind-numbing for the filtration consumer and lead to "analysis paralysis". Many times customers can't help but wonder - "What is the difference?"

In spite of the potential difficulty in choosing an appropriate method of oil purification, cleaning the oil in the system does have substantial benefits that are relatively easy to calculate using the known equipment cost, known maintenance costs and oil replacement costs. If oil purification only doubles the life of the oil, the cost savings are obvious - the cost associated with one oil changeout. Many times, oil purification will extend the life of the oil many times and as a result will extend the life of the equipment substantially as well so cost savings can be significant. These charts published by Noria Corporation in the January - February 2008 edition of Machinery Lubrication (page 22) demonstrate the potential life extention of equipment by improving the cleanliness level of the oil.

Potential Useful Life Extension of Hydraulics Based on Improving the Lubricant Cleanliness from the Initial to the Final Cleanliness Codes. (Courtesy of Noria)							
Final →	*/20/17	*/19/16	*/18/15	*/17/14	*/16/13	*/15/12	*/14/11
Initial ↓							
*/26/23	x5	x7	x9	x>10	x>10	x>10	x>10
*/24/21	x3	x4	x6	x7	x9	x>10	x>10
*/22/19	x1.6	x2	x3	x4	x5	x7	x8
*/20/17		x1.3	x1.6	x2	x3	x4	x5
*/19/16			x1.3	x1.6	x2	x3	x4

Potential Useful Life Extension of Gears Based on Improving the Lubricant Cleanliness from the Initial to the Final Cleanliness Codes. (Courtesy of Noria Corporation)							
Final →	*/20/17	*/19/16	*/18/15	*/17/14	*/16/13	*/15/12	*/14/11
Initial ↓							
*/26/23	x2.5	x3	x3.5	x4	x5	x6.5	x7
*/24/21	x1.5	x2	x2.5	x3	x4	x5	x6
*/22/19	x1.1	x1.3	x1.7	x2	x2.5	x3	x3.5
*/20/17		x1.05	x1.3	x1.4	x1.7	x2	x2.5
*/19/16			x1.1	x1.3	x1.5	x1.7	x2

The biggest reason to purify oil is to maximize the return on the investment in the oil. Keeping the oil clean also has the benefit of extending equipment life. Equipment owners should be using oil analysis to monitor condition of the oil and equipment and to determine when the oil should be replaced. When oil analysis is not being used and the oil is being replaced on a "time in service" basis only, many industries experts believe that at least 70% of that oil is being changed for contamination and not because the useful life of the oil has been used up. In other words, if the oil was just cleaned, it would still be useful. This is especially true for select, high quality base oil with enhanced, proprietary additive chemistry lubricants which tend to have a very long useful life.

So the question is - "What kind of filtration?" This question can be difficult to answer without some level of expertise and many people get frustrated that it isn't simpler. The difficulty stems from several inter-related factors, including; Oil Viscosity, Operating Temperature, Oil Type, Contamination Type, Contamination Level, How fast the oil is being contaminated, Equipment Type, Enviromental Contraints and on and on. Sometimes issues are not obvious and will arise during the process. Sometimes it is unknown if ANY solution will work and testing will be required first.

There are many choices. Let's first look at what some of the common choices are then discuss what solutions apply to what situations.

Type of Filtration	**Description**	**Examples**
Media Based Filtration	These systems use either a Full Flow or Depth filter cartridge to purify the oil.	1. Offline or Side Stream Systems permanently installed on Equipment 2. Filter Carts 3. Filter Skids
Magnets	These systems use magnets to attract and hold ferrous contamination	1. Inline magnets installed in the fluid stream 2. Magnet cartridges 3. Magnetic reservoir plugs
Coalescing Systems	These systems use some method to bring water molecules together with each other in order for gravity to separate the water from the oil and allow for draining the water off of the system. They utilize full flow or depth media to aid in purifying the oil.	1. Stand Alone Coalescing Chamber 2. Coalescing Chamber added to a filter cart. 3. Coalescing Skid for high volume (Up to 400 gpm)
Centrifugal Systems	These systems use a spinning bowl or disc to separate both water and solid contamination from the oil. They utilize heat and full flow media to aid in purifying the oil.	1. Centrifugal Skids or Trailers. These systems tend to be very large and are operated by contract firms that come on-site to spot clean the oil.
Vacuum Dehydration	These systems use vacuum to remove water from oil. They are useful for not only removing free and emulsified water, but also can remove dissolved water. They utilize heat and full flow or depth media to aid in purifying the oil	1. Vacuum dehydration Skids. These systems will be from 3 gpm small cart systems up to 50 gpm and larger skid systems

When recommending a filtration system for a particular application, some basic questions need to be answered first. The questionnaire on the following page is a useful tool for this job.

Equipment Oil Conditions Questionnaire for Determining Secondary Filtration Needs

Sales Representative		Customer	
Company Represented		Customer Contact Name	
Phone Number		Phone Number	
Email		Email	

Equipment Name		Oil to be filtered	
Equipment ID Number		Number of Gallons	
Equipment Location		Viscosity	
Operating Temperature		Date Oil in Service	
Special Conditions - (for example - explosion proof needed, equipment is outdoors, high or low ambient temperature)		Contamination known to be in the oil	
Does the equipment operate 24 hrs		How fast does the oil become contaminated	
Any special comments, concerns, notes or important information		Source of Known Contamination	
		Current ISO Cleanliness Code	
		Target ISO Cleanliness Code	
		Current Water Contamination Level	
		Target Water Level	

This information sheet will be used to help identify a solution for the above listed application. It is important to fill out as much information as is known and as completely as possible. Call AMS if you have any questions about filling out this form and a technician will be happy to assist you.

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What Kind of Filtration to Choose? (continued)

With the questionaire in hand, we can begin to determine a solution. The chart below helps to illustrate the application of these varied solutions. The chart is intended as a guide only and is not absolute. Experience plays a big part in selecting a proper filtration system. It is important when the situation is complicated to consult an experienced filtration expert. The recommendations should be both effective for the desired filtration and cost effective. Ultimately, secondary filtration is an investment and must provide sufficient return on the investment.

Type of Filtration	Useful	Not Useful
Media Based Filtration - This is the most common application used for secondary filtration. Utilizes either full flow or depth filtration to purify the oil. They are very simple to operate and maintain.	**Depth Media -** • Hydraulics • Gear oils • Lube Oils • Turbine Oils • Diesel Fuel / Fuel Oils	• When large volumes of water are present that will overwhelm the elements • Oils with Special Additive Packages (e.g. LE Duolec™) • When High Flow rates are needed (above 3 - 5 gpm per element) • High Viscosity (ISO 680) • Oil Temperatures above 250F
	Full Flow Media - • Hydraulics • Gear oils • Lube Oils • High Viscosity Oils • Diesel Fuel / Fuel Oils • Oils with Special Additive Packages • Water based fluids	• Will not remove water • Will not clean at as low of ISO Cleanliness codes as Depth Media • Will not hold as much solid contamination so filters will need replaced more often than Depth Media
Magnets - Simple to operate and Maintain	• Attract and hold ferrous contamination from all types of fluid	• Will not remove any other type of contamination
Coalescing Systems - Simple to operate and maintain. Not always reliable. Temperature, flow rate and oil type affect coalescing efficiency	• Gear oils • Lube Oils • Turbine Oils with Type I Base Oils or that have water release additive packages • Diesel Fuel / Fuel Oils	• Hydraulic Oils • Most modern Turbine Oils, especially most made with Type II Base Oils • Oil that does not release water well
Centrifugal Systems - Can be complicated to operate and are difficult to maintain. Usually require special training.	• Hydraulics • Gear oils • Lube Oils • Turbine Oils • Diesel Fuel / Fuel Oils	• Does not Work well with High Viscosity Oils • These systems tend not to remove solid contamination well. • These systems tend to be very large and difficult to operate. They are usually operated by contract firms that come on-site to spot clean the oil.
Vacuum Dehydration - Can be complicated to operate and does require special training. Usually easy to maintain. Is very effective for water removal. Is capable of removing dissolved water down below 5 ppm. These systems are always couples with Media Based Filtration.	• Hydraulics • Gear oils • Lube Oils • Turbine Oils - Vacuum Dehydration will remove water safely regardless of the Base Oil Type	• High Viscosity Oils (ISO 680) • When water contamination is NOT an issue

What is the Beta Rating on That Depth Element?

Beta ratings are an important piece of information for selecting filter elements. These ratings give an idea of how efficient a filter element will be at various contamination sizes. Beta Rating comes from the Multipass Method for Evaluating Filtration Performance of a Fin Filter Element (ISO 16889:1999) and expressed as a ratio of the number of particles of a certain size upstream of the filter media divided by the number of particles of that same size downstream of the filter media or;

$$\beta x = \frac{\text{Number of Particle X size upstream}}{\text{Number of Particles X size downstream}}$$

So for example, to calculate the beta rating of a filter media using 5 micron particles with 10 particles upstream and 1 particle downstream, the equation would be

$\beta 5 = 10/1$ so $\beta 5 = 10$

This means that the beta rating for this particular media at 5 microns is 10. This same media may have a rating at 10 microns of 200 and be the same media. I recommend reading the article "Understanding Filter Efficiency and Beta Ratios" by Jeremy Wright in the January-February 2008 edition of Machinery Lubrication published by Noria Corporation.

Beta Ratings are very important and useful for Full Flow filter elements. However, beta ratings do not give a good indication of the effectiveness of a Depth Media filter element. Depth media is typically rated using Nominal Ratings because it will have;

1. A very high Beta Rating at low micron levels because of the very long path of flow. This long flow path makes it very easy to achieve the high rating regardless of how effective the element is.
2. Depth Filter Elements are designed to filter differently than Full Flow elements.
3. Beta Rating will not demonstrate how effective the filter element actually is, especially at levels below 3 microns.

So, a depth filter with this very high Beta Rating may not be very good for the filtration task if it does not perform at the very low micron levels. In other words, a Depth Filter element with a beta rating of $\beta 5 = 1000$ can be very misleading if it isn't very efficient below that level. Also, Depth filters are usually employed for different reasons than Full Flow filter elements, particularly in applications with moisture contamination or on engines where depth filtration will be effective against soot and varnish. Beta ratings do not take such contamination into consideration in the calculation and therefore offer no assistance to the filter end user as to the effectiveness of the Depth Filter element.

When considering either Depth Media or Full Flow filter elements, the EFFECTIVENESS of the element is most important - How does the element perform in the real world. This is why ongoing oil analysis is so important so that an element that is not being effective can be replaced with one that is. The charts below illustrates some real world results and demonstrate the effectiveness of the particular elements.

Date	4/20/2007
Oil Filtered	ISO 32 HYD
	Hemsaw Hydraulic Reservoir
Customer	Perfect Filtration
Start ISO	21/19/15
Hour 214 ISO	18/16/13
Filter System	PFS-U-1000
Filter Element	AMS-304 - Depth Media

Date	9/10/2007
Oil Filtered	ISO 46 HYD - Lube Master
	Hydraulic Reservoir - CUBER
Customer	Arnan Development
Start ISO	24/22/18
Hour 241 ISO	19/17/13
Filter System	PFS-U1000
Filter Element	AMS-304 - Depth Media

Date	1/8/2008
Oil Filtered	ISO 46 HYD - AEON 6000
	New Oil 55 Gallon Drum
Customer	Cargill Co. - Hammond, IN
Start ISO	18/16/12
Hour 1 ISO	17/15/10
Hour 2 ISO	15/13/10
Hour 3 ISO	13/12/9
Filter System	C-08150-2-120
Filter Element	AMS-304 - Depth Media
Flow Rate	5-7 gpm

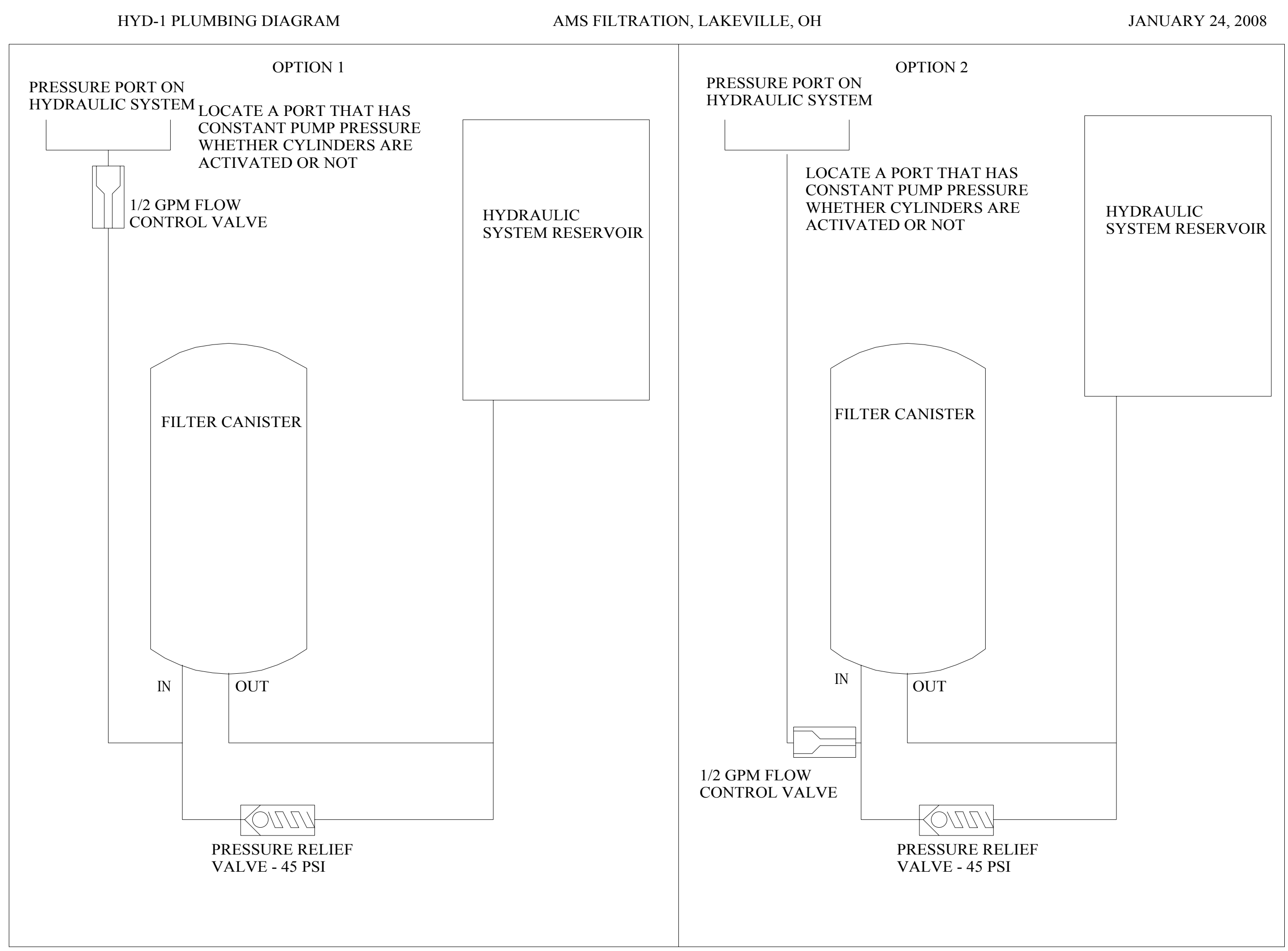
Date	2/27/2008
Oil Filtered	ISO 32 HYD - LE 6401
	Drum Fill Line
Customer	Lubrication Engineers - Wichita, KS
Start ISO	20/18/14
Single Pass ISO @ 35 PSI / 10 gpm	18/17/13
Single Pass ISO @ 45 PSI / 60 gpm	17/14/11
Filter System	AMS-1000-6x18-1.5
Filter Element	AMS-6x18-MG6 - Pleated MicroGlass
	Beta 200 @ 6 micron

Date	3/4/2008
Oil Filtered	ISO 220 GEAR - LE 6406
	Drum Fill Line
Customer	Lubrication Engineers - Wichita, KS
Start ISO	22/20/16
Single Pass ISO @ 55 PSI / 40 gpm	18/15/11
Filter System	AMS-1000-6x18-1.5
Filter Element	AMS-6x18-MG6 - Pleated Microglass
	Beta 200 @ 6 micron

Adding Filtration to Mobile Equipment

Adding filtration to mobile equipment takes two different paths. The first is for systems on the equipment that have their own pump, such as the hydraulic system or the engine. The other is for systems that do not have their own pump or the on board pump cannot be used. Examples of these systems are differentials, other gear boxes and transmissions.

Adding filtration to a mobile equipment system that has its own pump is referred to as side stream or offline filtration. These systems work by using the system pressure to take a small portion of the oil flow, filter it and then return it to the reservoir. It is called side stream or off line because it works next to the primary flow circuit or "off" the primary circuit, not in the primary circuit the way primary filtration does. Adding these systems are relatively simple but do require some expertise. For hydraulics, a constant pressure point in the system must be located and a pressure compensated flow control valve must be installed. The filter canister is mounted in a safe location on the equipment and a line is run from the flow control valve to the inlet of the canister. A pressure relief valve is also installed in this line and connected to the return line back to the reservoir to prevent a canister overpressure situation. From the outlet of the canister, a line is connected to the reservoir. The diagram below illustrates the installation on a hydraulic system.



An engine application is very similar, but has a flow orifice instead of a pressure compensated flow control valve and does not require a pressure relief valve.

For systems that do not have their own pumping system, a pump run by a DCV motor is included in the installation.