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Technical Reference Guide "The Blue Pages"

Donaldson provides this technical reference as a short course in "Hydraulic Filtration 101"—for those who want to gain a better understanding of fluid power filtration.

In industrial applications at factories all over the world, we too often see hydraulic circuits that don't include proper fluid filtration, or include it as an afterthought. Good filtration needs to be an integral part of the hydraulic circuit to ensure the long life and proper operation of the pumps, valves and motors. A $100 filter protects your $100,000 equipment.

This guide is offered to aid in choosing the filter that will help you achieve the ideal cleanliness levels and longest life for your critical components.

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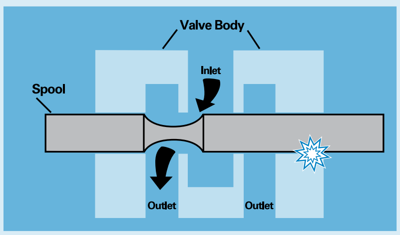
Symbols Used

ß	Beta Ratio
cSt	Centistokes
∆P	Pressure Drop or Differential Pressure
ISO	International Standards Organization
µm	Micron or micrometer
ppm	Parts per million
SSU SUS	Saybolt Seconds Universal

Hydraulic Components Need Protection

Fluid power circuits are designed in all shapes and sizes, both simple and complex in design, and they all need protection from damaging contamination. Abrasive particles enter the system and, if unfiltered, damage sensitive components like pumps, valves and motors. It is the job of the hydraulic filter to remove these particles from the oil flow to help prevent premature component wear and system failure. As the sophistication of hydraulic systems increases, the need for reliable filtration protection becomes ever more critical.

How Contamination Damages Precision Parts



This cutaway view of a simple hydraulic valve illustrates how particles damage components. In normal operation, the spool slides back and forth in the valve body, diverting oil to one side of the valve or the other. If a particle lodges between the spool and valve body, it will erode small flakes from the metal surfaces. As these flakes are moved back and forth by the action of the spool, they can roll into a burr that jams the spool and disables the valve.

Component Damage

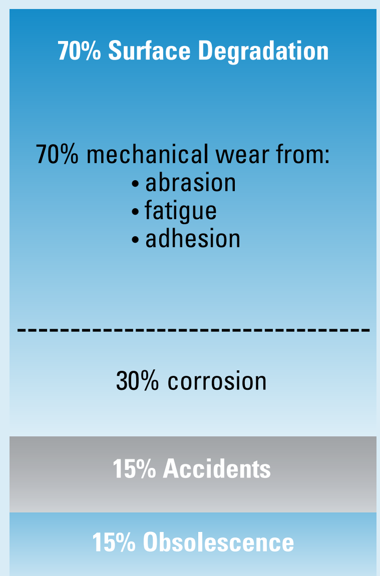
Looking down the barrel of an hydraulic cylinder, we can see the scratches along the inside surface. Don't cut costs by eliminating hydraulic filters. It could cost you more in the long run in major component repairs.

Types of Contaminant

- Many different types of contamination may be present in hydraulic fluid, causing various problems. Some are:
- Particulate (dust, dirt, sand, rust, fibers, elastomers, paint chips)
- Wear metals, silicon, and excessive additives (aluminum, chromium copper, iron, lead, tin, silicon, sodium, zinc, barium, phosphorous)
- Water
- Sealant (Teflon®* tape, pastes)
- Sludge, oxidation, and other corrosion products
- Acids and other chemicals
- Biological, microbes (in high water based fluids)

Typical Factors in Component Life

Studies show that most (typically 70%) of hydraulic component replacement is necessary because of surface degradation, and most of that is due to mechanical wear. Proper filtration of hydraulic fluids can lengthen component life.



* Teflon is a registered trademark of E.I. Dupont de Nemours & Co., Inc.

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Where Contamination Comes From

There are surprising number of different sources of system contamination in hydraulic filtration.

New Hydraulic Fluid

Adding new fluid can be a source; even though it's fresh from the drum, new hydraulic fluid isn't clean. (It may look clean, but, remember, the human eye can only see a particle the size of about 40 µm.) Oil out of shipping containers is usually contaminated to a level above what is acceptable for most hydraulic systems: typically, new fluid has a cleanliness level about the same as ISO Code 23/21/19, and water content is typically 200 to 300 ppm. Never assume your oil is clean until it has been filtered.

Built-In

Built-in contamination, also called primary contamination, is caused during the manufacture, assembly and testing of hydraulic components. Metal filings, small burrs, pieces of Teflon tape, sand and other contaminants are routinely found in initial clean up filtration of newly manufactured systems.

Ingressed

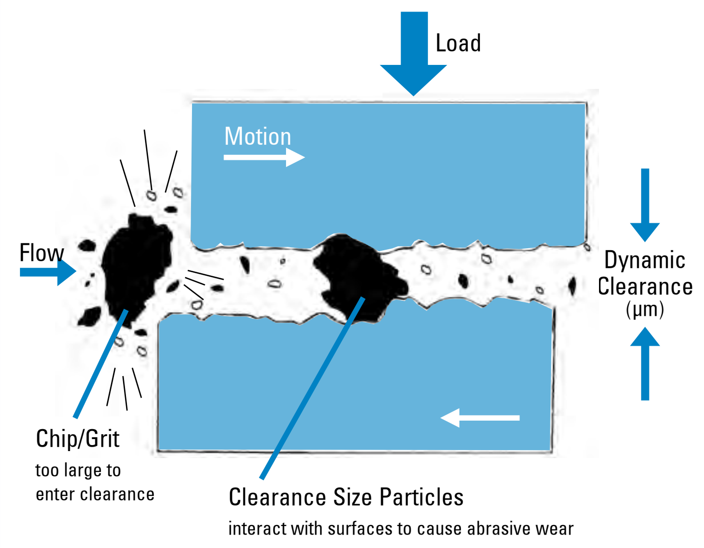
Ingressed or external contamination comes from the environment surrounding the system. Dirt can enter the hydraulic fluid supply through leaking seals, reservoir breather caps, and worn cylinder rod seals. Ingressed moisture, particularly, can cause long-term problems. As a hot system cools at night, cool moisture-laden air can be drawn into the reservoir; as the air condenses, water is released into the reservoir. Water in excess of 0.5% by volume in a hydrocarbon-based fluid accelerates the formation of acids, sludge and oxidation that can attack internal components, cause rust, and adversely affect lubrication properties. The severity of ingression and type of contaminant are dictated by the applications and environment.

Induced

Maintenance procedures can introduce contamination into the system. Opening the system allows airborne particles to enter. Leaving the system open during operation provides continuous ambient particle ingression. Keep your system closed as much as possible.

In-Operation

The major source of contamination are the pump and actuators, the hydraulic cylinder, or the hydraulic motor. Wear-generated contaminants are a hazard during normal hydraulic system operation. The circuit actually generates additional particles as the fluid comes into contact with the precision machined surfaces of valves, motors and pumps. Contaminant levels can keep doubling with every new particle generated. The result can be catastrophic if these contaminants are not properly filtered out of the system.



Rubber & Elastomers

Due to temperature, time, and high-velocity fluid streams, rubber compounds and elastomers degrade—thus releasing particulates into the fluid. This may be from hoses, accumulator bladders, seals, or other elastomer products.

High Water Based Fluids

The water in HWBF tends to support biological growth and generate organic contamination and microbes.

Replacement of Failed Components

Failure to thoroughly clean fluid conductor lines after replacing a failed hydraulic pump will cause premature catastrophic failure.

Donaldson recommends frequent oil sampling to ensure proper contamination control. Sample test points should be close to hydraulic pumps and at other key locations that provide safe, reliable access to the fluid while under full system pressure.

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Fluid Conditioning

Fluid Conditioning is the term for the overall conditioning of the fluid in the hydraulic system, and encompasses particulate removal via filters along with other various methods for removing silt, air, water, heat, acid, sludge or chemicals.

Particulate Removal

Particulate removal is usually done with mechanical filters. A well designed reservoir that allows settling will also help in keeping particulates out of the mainstream fluid. For ferrous particulates and rust, reservoir magnets or strainer band magnets can also be used. Other methods such as centrifuging or electrostatic filtration units can also be used, particularly in continuous batch processing and fluid reclamation.

Removal of Silt

Silt, defined as very fine particulate under 5 µm in size, requires very fine filtration or "oil polishing."

Air Removal

Getting air out of the system is best done by adding 100 mesh screen in the reservoir, approximately 30° from horizontal to coalesce entrained air and allow larger bubbles to rise to the surface when reservoir velocities are low.

Water Removal

A number of techniques exist to prevent water or moisture ingression or to remove water once it is present in a hydraulic or lube oil system. The best choice of technique for removal is dependant on the whether or not the water exists as a separate phase (dissolved or free), and also on the quantity of water present. For example, the presence of water or moisture can be reduced or prevented from entering a fluid reservoir through the use of absorptive breathers or active venting systems. However once free water is present in small quantities, water absorbing filters or active venting systems usually provide adequate removal means. For large quantities of water, vacuum dehydration, coalescence, and centrifuges are appropriate techniques for its removal. However, as each of these techniques operates on different principles, they have various levels of water removal effectiveness. The chart below provides comparative information on these techniques and their relative effectiveness. Care should be taken to apply the best technique to a given situation and its demands for water removal.

Chemical Removal

Removal of acids, sludge, gums, varnishes, soaps, oxidation products and other chemicals generally requires an adsorbent (active) filter with Fuller Earth, active type clays, charcoal, or activated alumina.

Heat Removal

Removing heat is important to maintain viscosity and prevent fluid breakdown. Usually performed with heat exchangers, including air-to-oil and water-to-oil types, finned coolers, or refrigerated units.

Heat Addition

Added heat is used for cold temp start-up to get fluid viscosities within operational limits. Use heaters, immersion or in-line.

Kidney Loop Filtration

One very effective way of ensuring thorough fluid conditioning is with a dedicated off-line circulation loop, or "kidney" loop, as illustrated below. Widely used in industrial applications, this system uses a separate circulation pump that runs continuously, circulating and conditioning the fluid. Multiple stages and types of filters can be included in the circuit, as well as heat exchangers and in-line immersion heaters. For further information on fluid conditioning, consult your fluid power supplier or a reputable manual.

Water Prevention/ Removal Techniques	Usage	Prevents Humidity Ingression	Removes Dissolved Water	Removes Free Water	Removes Large Quantities of Free Water	Limit of Water Removal
Adsorptive Passive Breather	prevention	Y				n/a
Active Venting System	prevention and removal	Y	Y	Y		down to <10% saturation
Water Absorbing Cartridge Filter	removal			Y		only to 100% saturation
Centrifuge	removal			Y	Y	only to 100% saturation
Coalescer	removal			Y	Y	only to 100% saturation
Vacuum Dehydrator	removal		Y	Y	Y	down to ~20% saturation

Proper Filter Application

When selecting a filter or replacement element, it's important to first answer some basic questions about your application. Where will the filter be used? What is the required cleanliness level (ISO code) of your system? What type of oil are you filtering? Are there specific problems that needed to be addressed?

It's also important to think about the viscosity of the fluid in your system. In some machinery lubrication applications, for example, the oil is very thick and has a tougher time passing through the layer of media fibers. Heating techniques and the addition of polymers can make the liquid less viscous and therefore easier to filter. Another option is to install a filter with larger media surface area, such as the Donaldson W041 or HRK10 low pressure filters, that can accommodate more viscous fluids.

Next, think about duty cycle and flow issues. Working components such as cylinders often create wide variations in flow—also called pulsating flow —that can be problematic for filters with higher efficiency ratings. On the other hand, dedicated off-line filtration (also called "kidney loop") produces a very consistent flow, so it makes sense to use a more efficient filter.

Filters used in applications with steady, continuous operation at lower pressures will last longer than filters that must endure cycles of high pressure pulsating flow. Generally, the lower the micron rating of a filter, the more often it needs to be changed since it is trapping more particles.

Finally, it's wise to ask yourself, *"How much is my equipment worth?"* Calculate how much it would cost to replace the equipment in your system, in case of component failure, and make sure those areas are well protected with proper filtration.
(For example, high performance servo valves are very sensitive, costly components that need to be protected with finer filtration media.)

Minimizing maintenance costs through good contamination control practices requires proper filter application based on the specific contamination problems. Good contamination control means cost-effective filtration. When looking for a filter, first assess the needs of your system and any problem areas.

System Characteristics to Consider When Specifying Filtration

1) Oil Viscosity
2) Flow
3) Pressure
4) What Components will be protected by the filter
5) Cleanliness level required (expressed in ISO code)
6) Type of oil/fluid
7) Environment (the system, the surrounding conditions, etc.)
8) Duty cycle
9) Operating Temperature

Fluid Properties

Lubricity The property of the fluid that keeps friction low and maintains an adequate film between moving parts.

Viscosity The thickness of the fluid as measured by resistance to flow. The fluid must be thin enough to flow freely, heavy enough to prevent wear and leakage. Hydraulic fluids thicken when they cool and thin out as they heat up. Because some hydraulic systems work under wide temperature extremes, viscosity can be an important factor.

Viscosity Index (VI) The rate of viscosity change with temperature: the higher the index, the more stable the viscosity as temperature varies. VI can sometimes be improved by additives, usually polymers.

Rust Resistance Rust inhibiting chemicals in hydraulic fluids help overcome the effects of moisture from condensation.

Oxidation Resistance Oxidation inhibitors delay the sludgy/acidic effects of air, heat, and contamination in the system.

Foaming Resistance Although control of foaming depends largely on reservoir design, anti-foaming additives in the fluid also help.

Types of Hydraulic Fluid

There are many kinds of fluids used for power, but they can basically be called petroleum-based fluids, biodegradable fluids, and fire-resistant fluids. A brief description of some of the types in each category are listed below; for details on these or others, consult your fluid power supplier or refer to a reputable manual on hydraulics, such as the Lightning Reference Handbook, published by Berendsen Fluid Power, Whittier, CA 90601.

Petroleum Based (Hydrocarbon)

These are the most commonly used fluids in hydraulic systems. Their major advantages are low cost, good lubricity, relatively low/non-toxicity, and common availability. This type of fluid is not just plain oil; rather, it is a special formulation with additives that make it suitable for hydraulic systems. Mostly, the additives inhibit or prevent rust, oxidation, foam and wear.

Variations:

- Straight oils: same as petroleum-based oil but without the additives.
- Automatic transmission fluids (ATF): excellent low temp viscosity and very high VI.
- Military hydraulic fluids (ie: MIL-H-5606 and MIL-H-83282): also called 'red oil' because of the color. Low viscosity, good for cold temp operations, but may have to be modified for pumps.

Fire Resistant Fluids

There are two types of fire-resistant fluids commonly used in hydraulic applications: Phosphate Esters and High Water Based Fluids (HWBF). Although generally not as viscous at cold temperatures as petroleum-based fluids, they are fire resistant due to their high content of noncombustible material. Very useful in overcoming the likelihood of fire caused by a broken hydraulic line spraying petroleum fluid into a pit of molten metal, onto a hot manifold, into a heat-treating furnace, or other ignition source.

Some types of HWBF:

- Oil-in-water emulsions (HFA): typically 95% water and 5% oil, with the oil droplets dispersed throughout the water. Provide some fire resistance, but due to oil content, other fluids are superior.
- Water-in-oil emulsions (invert emulsion HFB): typically 40% water and 60% oil, with the water dispersed in the oil. Provide some fire resistance, but due to oil content, other fluids are superior.
- Water-glycol (HFC): typically 40% water and 60% glycol. Excellent fire resistance. Since glycol is an antifreeze, water-glycol can be used at lower temps.

NOTE: HWBF may require reduced pressure rating of pumps and other components.

HFD Fluids

The HFD group contains several different types of synthetic products considered as such because they contain neither petroleum oil nor water. Phosphate ester fluids were the first HFD fluids and are the most fire resistant within the HFD family. Not as popular today, their use declined due to poor environmental performance, limited compatibility, and high cost. Certain phosphate esters have very high auto-ignition temperatures and are still used in specific applications, such as aircraft and power generation. A common brand is known as Sydrol® (registered trademark of Solution, Inc.). Skydrol requires EPR seal for chemical compatibility. Today most phosphate esters have been replaced by polyol esters. Based on organic esters, polyol esters are the most common HFD fluids used today. They offer good inherent fire resistance, good compatibility with system materials, excellent hydraulic fluid performance, and easy conversion from petroleum oil. In addition, the organic nature of these fluids gives them good environmental performance in biodegradability and aquatic toxicity. Another type of synthetic, fire resistant fluids have been formulated for certain niche markets. Water free polyalkylene glycols (PAGs) feature extended fluid life and good environmental performance. Technically an HFD fluid, PAGs (also known as polyalphaolefins (PAOs)are more often used for their biodegradability and overall environmental friendliness. This group also contains the synthetic silicone (siloxane) oils, known for their anti-foaming properties.

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Biodegradable

With increasing concern about the environmental impact of hydraulic system leaks and spills, biodegradable fluids are receiving expanded usage, particularly in Europe. There are two types of common biodegradable hydraulic fluids: 1) vegetable-based oils, such as sunflower or rapeseed oils, and 2) synthetic oils like diesters, etc. Generally, systems using biodegradable fluids are derated for maximum and minimum temperatures. Users who replace standard hydraulic oils with biodegradable oils must check with filtration component manufacturers to confirm that the fluid and components are compatible.

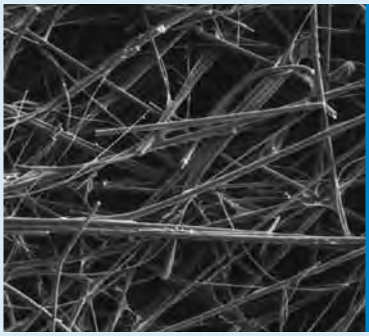
Basic Hydraulic Filtration Principles

Filter Media

Media is a term used to describe any material used to filter particles out of a fluid flow stream. There are four basic types used to remove contamination in hydraulic applications:

A. Synthetic Media

Synthetic fibers are man-made, smooth and rounded of provide the least resistance to flow. Their consistent shape allows us to control the fiber size and distribution pattern throughout the media mat to create the smoothest, least inhibited fluid flow.



Donaldson's Synthetic Media: Synteq®

Photo of Donaldson Synteq® synthetic filter media as seen magnified hundreds of times under the scanning electron microscope. The smooth rounded fibers provide low resistance to fluid flow.

Consistency of fiber shape allows the maximum amount of contaminant-catching surface area and specific pore size control. The result is media with predictable filtration efficiencies at removing specified contaminants (e.g., 4 μm) and maximum dirt holding capacity.

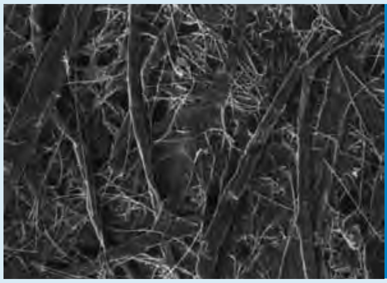
The low resistance of synthetic media to fluid flow makes it ideal for synthetic fluids, water glycols, water/oil emulsions, HWCF, and petroleum-based fluids.

B. Cellulose Media

Cellulose fibers are actually wood chips, microscopic in size and held together by resin. As you see in the photo below, the fibers are irregular in both shape and size.

Celluose often has lower beta ratings, which means there are smaller pores in the media. Smaller media pores cause more flow resistance, in turn causing higher pressure drop.

While cellulose provides effective filtration for a wide variety of petroleum-base fluids, in certain applications it results in poor filtration performance as compared to synthetic media.



Cellulose filter media photo from scanning electron microscope magnified hundreds of times.

C. Water Removal Media

This is media formulated with dessicants and resins to remove moisture and condensation from petroleum-based fluids. (For concentration of water greater than half of 1 percent (0.05%) in the hydraulic oil, we recommend you use a vacuum dehydrator unit.)

D. Wire-Mesh Media

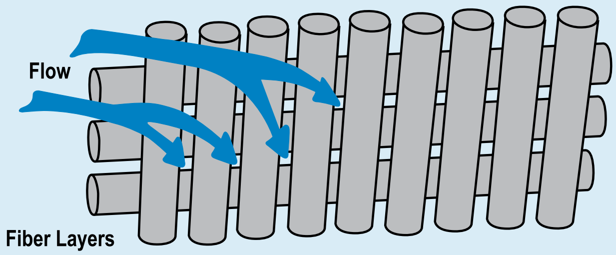
Wire-mesh media consists of stainless steel, epoxy-coated wire mesh available in 3 mesh sizes:

- 100 mesh yields 150 μm filtration
- 200 mesh yields 74 μm filtration
- 325 mesh yields 44 μm filtration

Typically wire-mesh filters will be applied to catch very large, harsh particulate that would rip up a normal filter. You may also find this media useful as a coarse filter in viscous fluid applications.

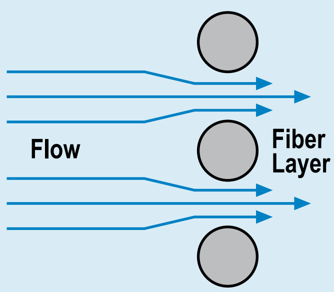
How Filter Media Functions In a Filtration System

The job of the media is to capture particles and allow the fluid to flow through. For fluid to pass through, the media must have holes or channels to direct the fluid flow and allow it to pass. That's why filter media is a porous mat of fibers that alters the fluid flow stream by causing fluid to twist, turn and accelerate during passage



The fluid changes direction as it comes into contact with the media fibers, as illustrated above. As the fluid flows through the media, it changes direction continuously as it works its way through the maze of media fibers. As it works its way through the depths of the layers of fibers, the fluid becomes cleaner and cleaner. Generally, the thicker the media, the greater the dirt-holding capacity it has.

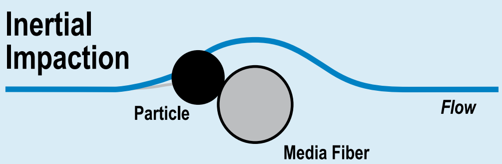
Looking at a cross-section view of the fibers, we can see how the flowstream is accelerated as it flows into the spaces between the fibers.



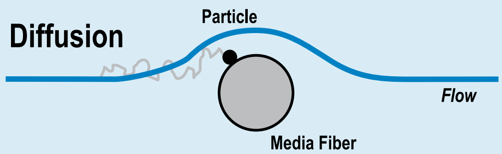
How Filter Media Collects Particles

There are four basic ways media captures particles.

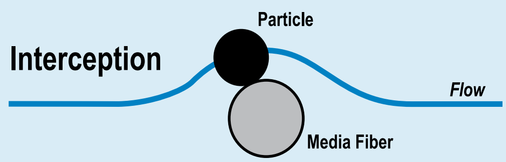
The first, called **inertia**, works on large, heavy particles suspended in the flow stream. These particles are heavier than the fluid surrounding them. As the fluid changes direction to enter the fiber space, the particle continues in a straight line and collides with the media fibers where it is trapped and held.



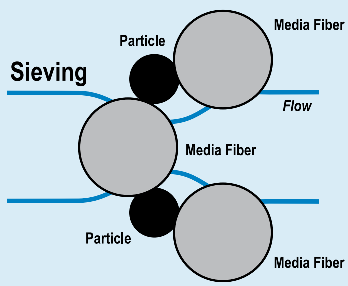
The second way media can capture particles is by **diffusion**. Diffusion works on the smallest particles. Small particles are not held in place by the viscous fluid and diffuse within the flow stream. As the particles traverse the flow stream, they collide with the fiber and are collected.



The third method of particle entrapment is call **interception**. Direct interception works on particles in the mid-range size that are not quite large enough to have inertia and not small enough to diffuse within the flow stream. These mid-sized particles follow the flow stream as it bends through the fiber spaces. Particles are intercepted or captured when they touch a fiber.



The fourth method of capture is called **sieving** and is the most common mechanism in hydraulic filtration. As shown at right, this is when the particle is too large to fit between the fiber spaces.



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Donaldson Filter Media Efficiency Ratings per ISO 16889 Test Standards

ISO 16889 is the international standard for Multi-Pass Testing to determine the efficiency (beta rating or beta ratio) and the dirt-holding capacity of the filter element. It replaced the ISO 4572 test standard.

Donaldson filter media has been re-tested per the new standard and the current beta ratios are shown at right. New beta ratios are shown at 200 and 1000, with a (c) to indicate test adherence to the ISO 16889 standard and traceability to NIST test dust.

Fluid to be Filtered	Recommended Media
Petroleum-based	Synteq Cellulose
Phosphate Ester	Synteq
Diester	Synteq
Water Glycol	Synteq
Water-Oil Emulsion	Synteq
Biodegradable Fluid	Synteq
HWCF (high water content fluids)	Synteq
Coarse Filtration	Wire Mesh

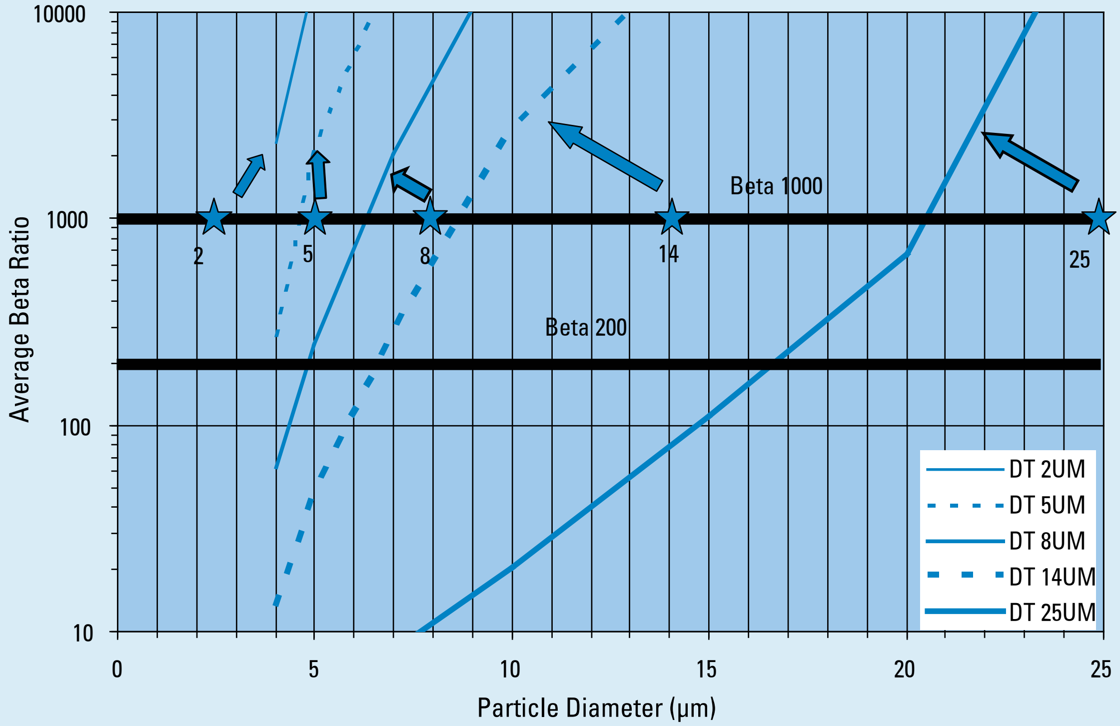
NEW Donaldson Filter Media Efficiency Ratings Per ISO 16889 Test Standards

Media Number	FORMER Rating $Beta_x$=75 per ISO 4572	NEW Rating $Beta_{x(c)}$=200 per ISO 16889	NEW Rating $Beta_{x(c)}$=1000 per ISO 16889
Donaldson Synteq® Synthetic Media			
No. ½	2 μm	<4 $μm_{(c)}$	<4 $μm_{(c)}$
No. 1	3 μm	4 $μm_{(c)}$	6 $μm_{(c)}$
No. 2	5 μm	5 $μm_{(c)}$	9 $μm_{(c)}$
No. 2½	10 μm	8 $μm_{(c)}$	10 $μm_{(c)}$
No. 3	15 μm	12 $μm_{(c)}$	14 $μm_{(c)}$
No. 4	16 μm	15 $μm_{(c)}$	20 $μm_{(c)}$
No. 6	13 μm	10 $μm_{(c)}$	13 $μm_{(c)}$
No. 9	22 μm	18 $μm_{(c)}$	23 $μm_{(c)}$
No. 16	37 μm	16 $μm_{(c)}$	22 $μm_{(c)}$
No. 20	40 μm	>50 $μm_{(c)}$	>50 $μm_{(c)}$
Donaldson Cellulose Media			
No. 3	16 μm	18 $μm_{(c)}$	24 $μm_{(c)}$
No. 10	25 μm	19 $μm_{(c)}$	23 $μm_{(c)}$
No. 15	35 μm	25 $μm_{(c)}$	29 $μm_{(c)}$
No. 25	N/A	32 $μm_{(c)}$	>40 $μm_{(c)}$
Donaldson Wire Mesh Media			
No. 44	45 μm nominal		
No. 74	75 μm nominal		
No. 149	150 μm nominal		
Donaldson Triboguard™ Synteq Synthetic Media			
DT 2UM	N/A	<4 $μm_{(c)}$	<4 $μm_{(c)}$
DT 5UM	N/A	4 $μm_{(c)}$	5 $μm_{(c)}$
DT 8UM	N/A	6 $μm_{(c)}$	8 $μm_{(c)}$
DT 14UM	N/A	10 $μm_{(c)}$	14 $μm_{(c)}$
DT 25UM	N/A	20 $μm_{(c)}$	25 $μm_{(c)}$

NEW! Donaldson Triboguard™ Synteq® Media

The chemical and thermal compatibility of fluid filters is an increasingly difficult design challenge due to the complex variety of fluid systems. Today's fluid systems are often tailored towards the special needs fire resistance, biodegradability, and electrical insulating ability. Fortunately, there are chemical solutions available to meet these challenges. The Donaldson Triboguard grades of Synteq media utilize a blend of borosilicate glass fiber whose matrix is bonded together with an epoxy-based resin system. Donaldson filter media scientists found this to provide the best available chemical resistance for the broadest array of hydraulic, fuel, and lube oil filtration applications.

Donaldson Triboguard Synteq Media



Hydraulic Filtration Pressure Drop

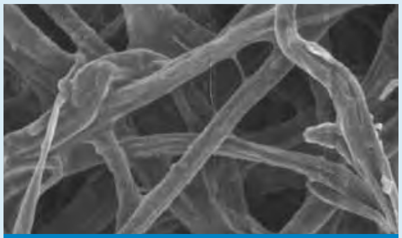
The difference between the inlet pressure and the outlet pressure is called pressure drop or differential pressure. It's symbolized by ΔP. ΔP is an irrecoverable loss of total pressure caused by the filter, and is mostly due to frictional drag on the fibers in the media.

ΔP may increase as the particulate rating or efficiency of the filter (as expressed by its beta ratio) gets better. ΔP also increases as the filter is being loaded with contaminant.

Four Major Factors Contribute to Pressure Drop

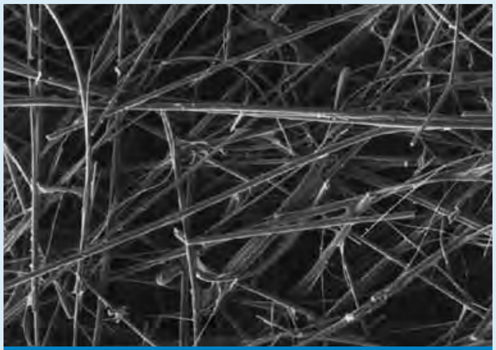
1. Filter Media

Media is, of course, the main factor influencing pressure drop; indeed, it causes pressure drop. That's why having a low-friction, high-flowing media is so important. The natural cellulose or paper fibers (shown at left) typically used in filtration are large, rough, and as irregular as nature made them.



Natural Fiber Cellulose media, as seen under the scanning electron microscope.

Donaldson developed a synthetic media with smooth, rounded fibers, consistently shaped so that we can control the fiber size and distribution pattern throughout the media mat, and still allow the smoothest, least inhibited fluid flow. Our synthetic media is named Synteq®.



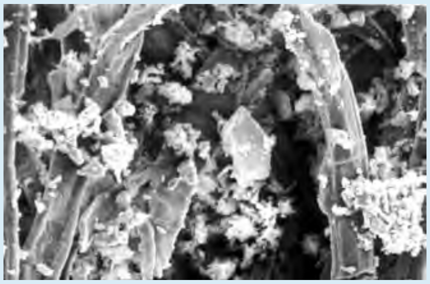
Donaldson's synthetic Synteq filter media — photo from scanning electron microscope — magnified hundreds of times.

Synteq fibers offer the least amount of resistance to fluid passing through the media. Consistency of fiber shape allows the maximum amount of contaminant-catching surface area and specific pore size control. The result is media with predictable filtration efficiencies at removing specified contaminants (i.e., 4 μm) and maximum dirt holding capacity.

Natural cellulose fibers are larger than synthetic fibers and jagged in shape, so controlling size of the pores in the media mat is difficult and there is less open volume. In most applications this results in higher ΔP as compared to synthetic filters. Higher beta ratings mean there are smaller pores in the media; smaller media pores cause more flow resistance, in turn causing higher pressure drop.

2. Dirt, Contaminant

As dirt gets caught in the media, it eventually begins to build up and fill the pore openings. As the pore openings shrink, the differential pressure (pressure drop) increases. This is called restriction. This photo from our scanning electron microscope shows actual dirt particles building up in the media pores.



Excessive dirt in the media can cause dirt migration or even filter failure. Dirt migration occurs when the restriction is so great that the differential pressure pushes dirt deeper into the media and, eventually, through the media and back into the system. Filter failure occurs when the restriction becomes so high that the filter cartridge collapses (outside-in flow) or bursts (inside-out flow) to relieve the upstream pressure.

To avoid such catastrophe, use of a filter service indicator is recommended. It measures the pressure drop across the filter, then signals when the filter is 'full' and needs to be changed.

3. Flow

Higher flows create higher pressure drop. With fast moving fluid, there will be more friction causing higher pressure drop across the media.

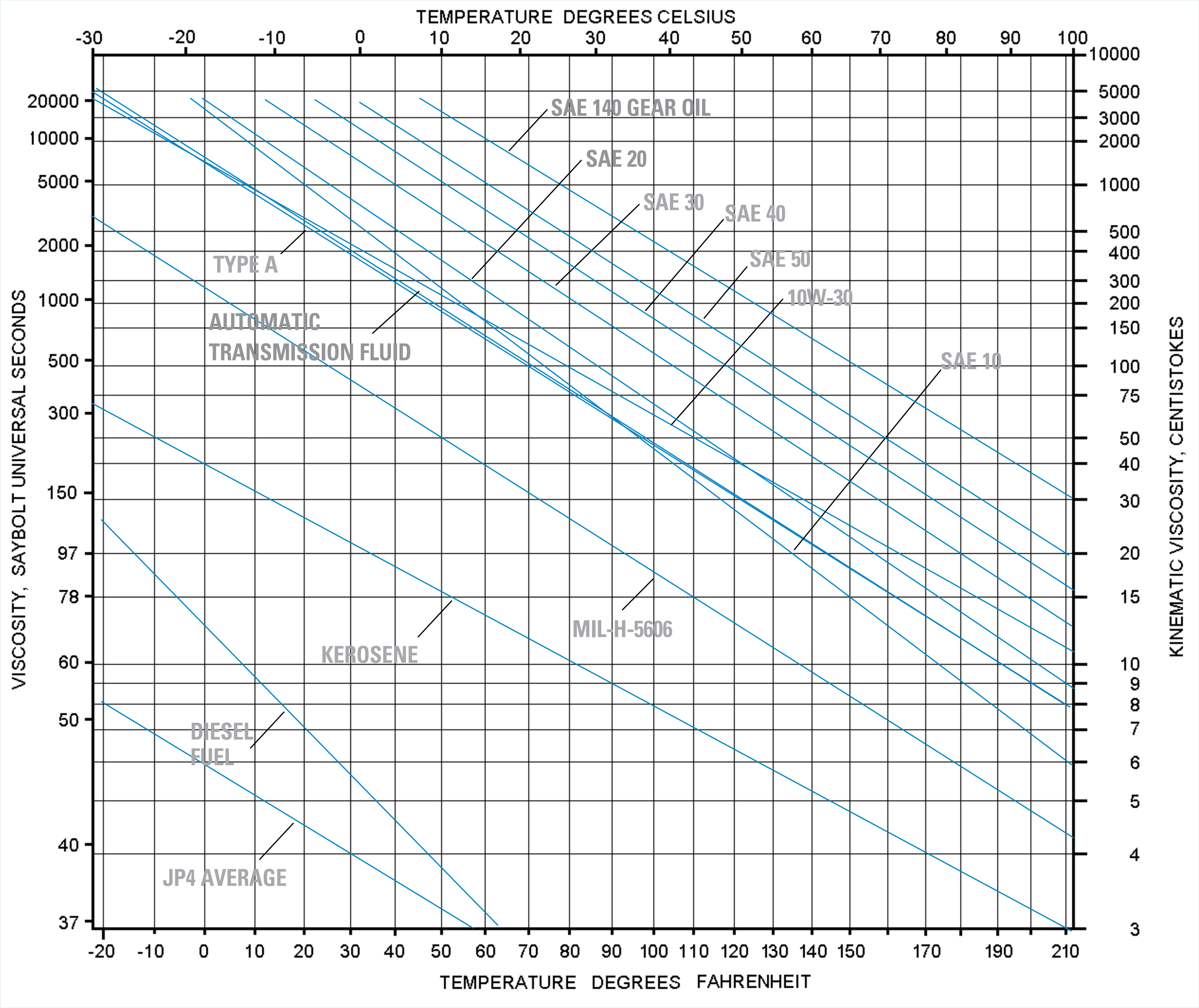
4. Fluid Viscosity

Measured in centistokes (cSt) or Saybolt Seconds Universal (SSU or SUS), fluid viscosity is the resistance of a fluid to flow. As fluid viscosity increases, the cSt rating increases. Higher fluid viscosities also mean higher pressure drop because the thicker oil has a tougher time passing through the layer of media fibers. Cold start fluid is a good example of highly viscous fluid. See chart below.

Filter media, amount of contamination, the flow rate, and fluid viscosity are all factors in the importance of sizing the filter for the system requirements. Filters that are too small won't be able to handle the system flow rate and will create excessive pressure drop from the start. The results could be filter operation in the bypass mode, filter failure, component malfunction, or catastrophic system failures. Filters that are too large for the system can be too costly. Oversized filters require more system oil and higher cost replacement elements. Optimal sizing is best.

Viscosity/Temperature Chart

A.S.T.M. Standard Viscosity-Temperature Chart for Liquid Petroleum Products (D 341-43) Saybolt Universal Viscosity



Physical Characteristics of Elements

There are two main differences in filter elements. The first is the design of the filter element itself, and the second is the type of media that is used in such elements.

Filter elements have some attributes that are immediately obvious to the casual observer, such as height, inside diameter, outside diameter, media concentration, type of liner, seal design, and the way the media and componets are glued or potted together.

- **Liners** must be structurally sturdy to withstand pressure variance, yet open enough to allow good flow.
- **Top seal** design must be leak-free, with a gasket or sealing device that ensures a good seal throughout the life of the filter. Standard seals are made of BunaN material, which is fine for most applications. However, if the filtered fluid is diester or phosphate ester fluid, you'll need a seal made of a fluoroelastomer such as Viton.
- **Media potting** is key since it holds the media in place at each end. Not only should the potting be fully around the ends of the media to prevent leaks, it should also be of a material that can withstand the application. For instance, epoxy potting should be used in elements that must perform in higher temperature environments, phosphate ester fluids and some high water based fluids.

Inside the element, the filter media can vary in thickness, pleat depth and pleat concentration.

For example, Donaldson hydraulic filters are generally equipped with either white ("Synteq" our synthetic material) or natural brown (paper or cellulose material) media. *It is important to note that media colors vary according to each manufacturer—it should not be assumed that any white-colored media is made of synthetic material.*

Some of the most important characteristics of a filter element (structure, fiber diameter, volume solidity, basis weight, thickness, layering) can only be detected under a microscope.

Damaged Equipment

Damage happens when key filtration points are ignored! The pistons in this pump are severely damaged from contamination in the oil.

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Combining the ISO Rating and Filter Performance Ratings

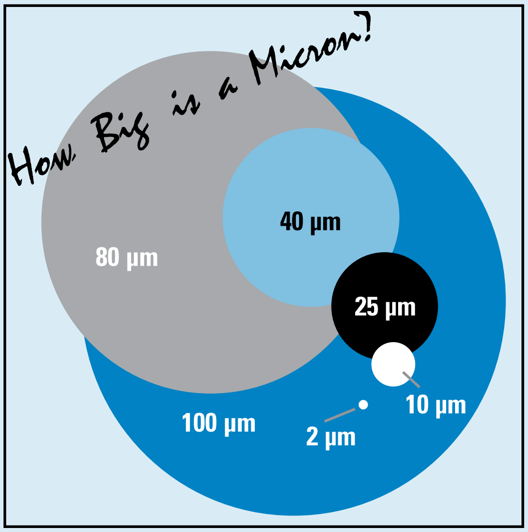
While filter manufacturers publish beta ratings for filter media to describe efficiency performance levels, a direct connection between the beta rating scale and the ISO rating scale cannot be made.

The solution is monitoring filter media performance at removing particles in the 4 µm, 6 µm, and 14 µm ranges. Oil analysis and field monitoring are the only ways to get these measurements. Combine data from several tests to form a range of performance. Remember, actual filter performance will vary between applications.

Here's how to determine which filter media will best protect your hydraulic components: plot any media performance range on the Application Guide to Donaldson Filter Media (page 246), then connect the dots to make a line. On the same graph, plot your component requirement. (Reference chart below for some popular components, or ask your supplier for the recommended ISO rating.) If the line of the media falls below the ISO line, or if the bottom line of the filtration range does not intersect the ISO line, the component will be protected.

Micron Sizes of Familiar Particles

Grain of table salt	100 µm
Human hair	80 µm
Lower limit of visibility	40 µm
White blood cell	25 µm
Talcum powder	10 µm
Red blood cell	8 µm
Bacteria	2 µm
Silt	<5 µm



Typical ISO Cleanliness

Here are some typical ISO cleanliness recommendations from component manufacturers. (These are guidelines; always check the ratings specified by the manufacturer of your specific components.)

Pressure	<3000 PSI ≤210 Bar	>3000 PSI >210 Bar
Pumps		
Fixed Gear Pump	19/17/15	18/16/13
Fixed Vane Pump	19/17/14	18/16/13
Fixed Piston Pump	18/16/14	17/15/13
Variable Vane Pump	18/16/14	17/15/13
Varibale Piston Pump	17/15/13	16/14/12
Valves		
Directional (solenoid)	20/18/15	19/17/14
Pressure (modulating)	19/17/14	19/17/14
Flow Controls (standard)	19/17/14	19/17/14
Check Valves	20/18/15	20/18/15
Cartridge Valves	20/18/15	19/17/14
Load-sensing Directional Valves	18/16/14	17/15/13
Proportional Pressure Controls	18/16/13	17/15/12*
Proportional Cartridge Valves	18/16/13	17/15/12*
Servo Valves	16/14/11*	15/13/10*
Actuators		
Cylinders	20/18/15	20/18/15
Vane Motors	19/17/14	18/16/13
Axial Piston Motors	18/16/13	17/15/12
Gear Motors	20/18/15	19/17/14
Radial Piston Motors	19/17/15	18/16/13

* Requires precise sampling practices to verify cleanliness levels.
Source: Vickers

Disaster Strikes

When filters are not a main component of the hydraulic circuit, disaster awaits. Here, piston rings were eaten away by contaminants.

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Media Application Guide and ISO Rating System

The Application Guide for Donaldson Filter Media on page 246 provides a data format for rating fluid contamination level and plotting filter media performance.

The vertical numbers on the left side of the chart represent particle counts in a logarithmic progression of ten: .01, .1, 1,10, 10^2, 10^3, 10^4, 10^5 and 10^6. (This represents the number of particle in the oil sample at the given size.) The numbers across the bottom of the chart represent particle size in microns.

Donaldson media efficiency performance levels are derived from the ISO 16889 test standard with NIST-certified on-line automatic particle counters and ISO medium test dust. The Donaldson media efficiency performance levels shown are based on test averages under steady flow conditions. Actual performance levels may vary by application, viscosity, flow variance and contamination differences. Contact Donaldson or your Donaldson distributor for specific application calculations.

The international rating system for fluid contamination levels is called the ISO contamination code and it is detailed in the ISO 4406 document. Most component manufacturers publish filtration level recommendations using the ISO code. The ISO code, located on the right side of the media application guide on page 246, is easy to use if you remember the 4 µm, 6 µm and 14 µm numbers along the bottom of the chart.

Manufacturer's ISO contamination levels are based on controlling the particle counts of 4 µm, 6 µm and 14 µm particles in hydraulic system oil. This level is identified by measuring the number of particles 4µm and greater, 6 µm and greater, and 14 µm and greater in one milliliter of the system hydraulic oil sample.

How to Use the ISO Rating

Example: A cartridge valve manufacturer recommends an ISO cleanliness level of 18/16/13.

1) On the Application Guide for Donaldson Filter Media on the next page, place a dot on the vertical 4 µm line, horizontally even with the 18 box of the ISO code.

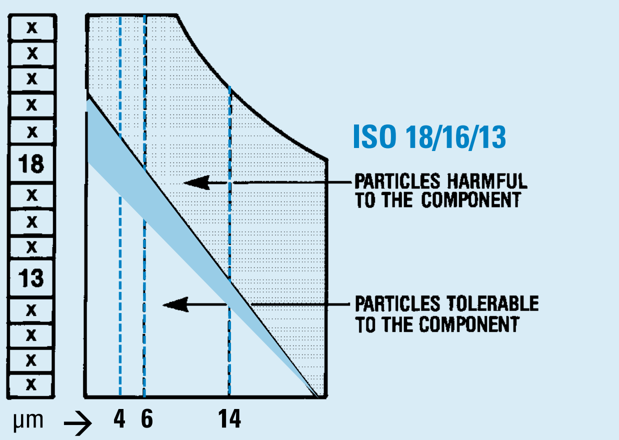
2) Place a dot on the vertical 6 µm line horizontally even with the 16 box of the ISO code.

3) Place a dot on the vertical 14 µm line horizontally even with the 13 box of the ISO code.

4) Connect the dots to get the ISO cleanliness level 18/16/13.

As illustrated below, particle counts falling on and above the 18/16/13 line are damaging to the component and exceed the 18/16/13 specification set by the manufacturer.

Select a Donaldson media that falls below 18/16/13 to achieve cleanliness level tolerable to the component.



ISO 4406 Contamination Code

This correlates to the numbers in the boxes along the right side of the graph on the next page.

Range of number of particles per milliliter:

Code	More Than	Up to & Including
24	80,000	160,000
23	40,000	80,000
22	20,000	40,000
21	10,000	20,000
20	5,000	10,000
19	2,500	5,000
18	1,300	2,500
17	640	1,300
16	320	640
15	160	320

Code	More Than	Up to & Including
14	80	160
13	40	80
12	20	40
11	10	20
10	5	10
9	2.5	5
8	1.3	2.5
7	.64	1.3
6	.32	.64

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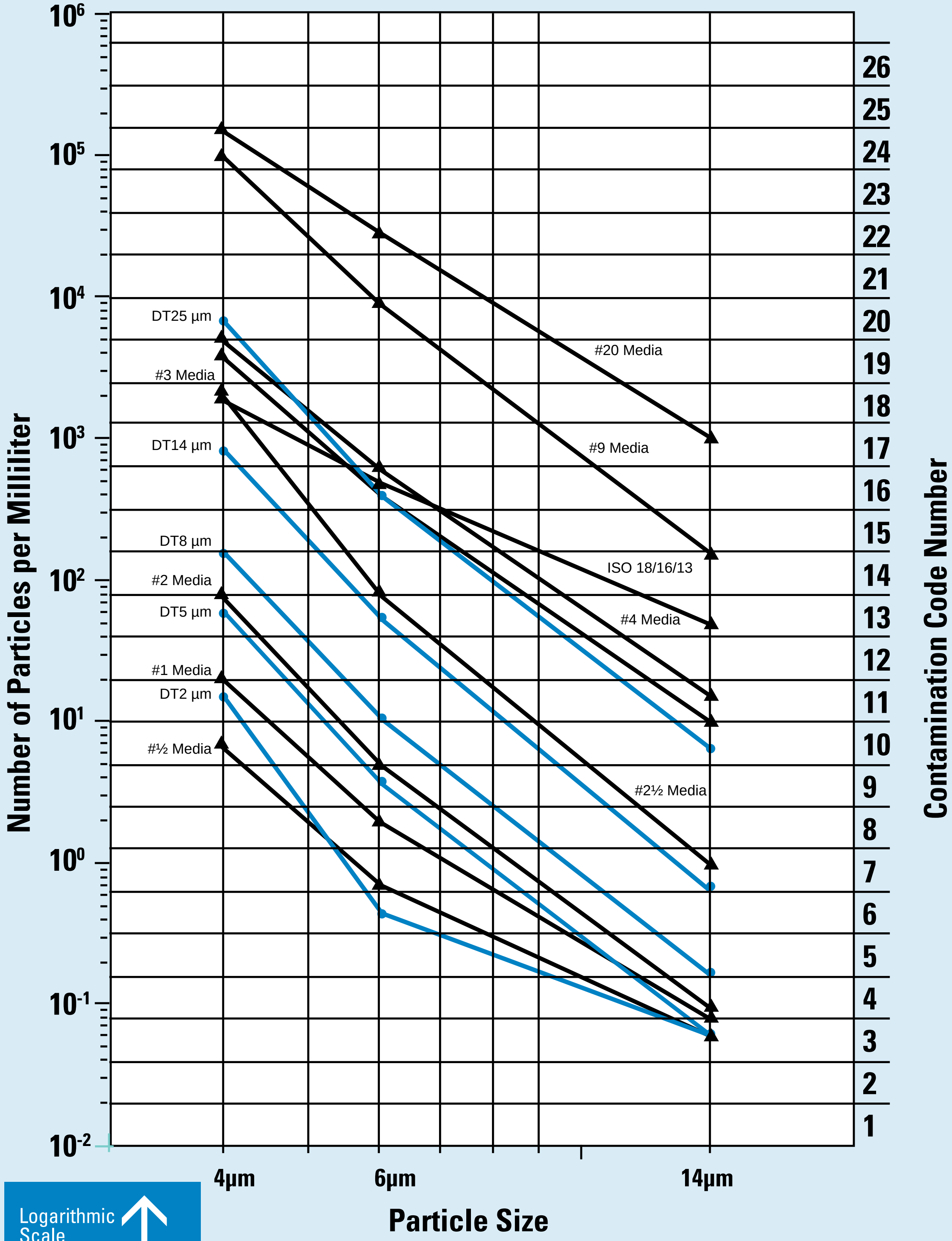
Application Guide for Donaldson Filter Media



Logarithmic Scale

This represents the number of particles at a given size in the oil sample

Filter Efficiency Standards

Understanding the Beta Rating System

This information is provided as an aid to understanding fluid filter efficiency terminology based on current ISO, ANSI and NFPA test standards. It is not proprietary and may be reproduced or distributed in any manner for educational purposes.

What is Beta Ratio?

Beta ratio (symbolized by ß) is a formula used to calculate the filtration efficiency of a particular fluid filter using base data obtained from multi-pass testing.

In a multi-pass test, fluid is continuously injected with a uniform amount of contaminant (i.e., ISO medium test dust), then pumped through the filter unit being tested. Filter efficiency is determined by monitoring oil contamination levels upstream and downstream of the test filter at specific times. An automatic particle counter is used to determine the contamination level. Through this process an upstream to downstream particle count ratio is developed, known as the beta ratio.

The formula used to calculate the beta ratio is:

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

where (x) is a given particle size

Indicates that testing was done with APC's calibrated with NIST fluid

$$ß_{10(c)} = 1000$$

1000 times more particles upstream than downstream that are 10 µm and larger

Why the Efficiency Rating Test Standard was Updated

The International Industry Standard (ISO) for multi-pass testing provides a common testing format for filter manufacturers to rate filter performance. This standardization gives you the ability to reliably compare published filter ratings among different brands of filters.

ISO test standards were updated in 1999 to reflect the improved technology available in particle counters and other test equipment. The newer particle counters provide more precise counting and greater detail— reflecting a truer indication of filter performance.

The National Fluid Power Association (NFPA), the National Institute of Standards & Technology (NIST), and industry volunteers, including several engineers from Donaldson, helped revise the ISO standard. ISO 16889 has been in force since late 1999 and ISO 4572 is officially discontinued.

Better Test Dust

The old test dust (AC fine test dust or ACFTD) was "ball milled," which produced dust particles of varying size and shape. Particle distribution was often different from batch to batch. The accuracy of ACFTD distribution and previous APC calibration procedure was questioned by industry, due to lack of traceability and certification. ACFTD hasn't been produced since 1992.

Now, the new test dust (ISO medium test dust) is "jet milled" to produce consistent particle size, shape, and distribution from batch to batch. See dust size comparison chart below.

Liquid Automatic Particle Counters (APC's)

In the old test standard (ISO 4572), fluid samples obtained in bottles and off-line particle counting were allowed. Now, in the updated standard (ISO 16889), on-line, laser-based automatic particle counters, especially made for measuring liquids, are required and bottle counting methods are disallowed, as illustrated on next page.

Find further information on ISO 16889
at www.NFPA.com or your ISO document source.
Ask for ISO/TR16386: 1999 "The Impact of
Changes in ISO Fluid Power Particle Counting—
Contamination Control and Filter Test Standards."

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The old particle counter calibration was based on only 1 dimension of an irregularly-shaped particle (the longest cord). Today, the particle counter calibration is based on equivalent spherical area of an irregularly-shaped particle.

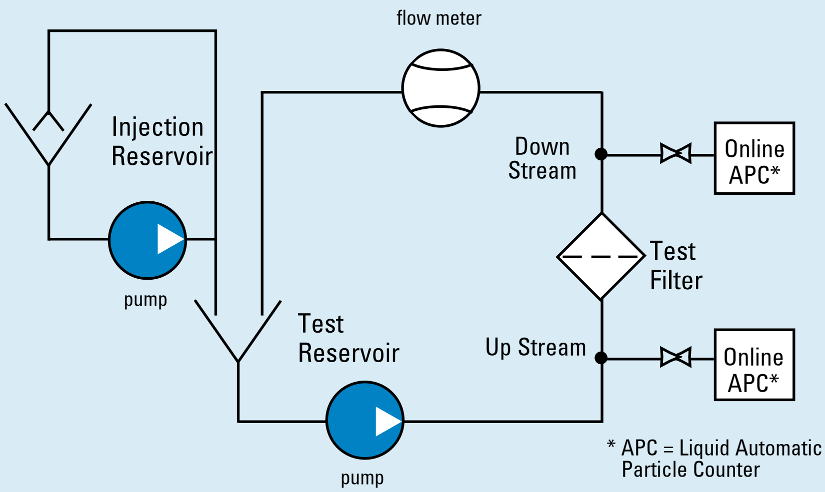
NIST provides calibration suspension, which is certified with X number of particles at a certain size. This is verified by NIST. The new way to list beta ratios includes a subscript (c) to indicate NIST certified test suspension and assures you of traceability and repeatability.

Overall, you can have strong confidence in filter ratings resulting from tests per ISO 16889, as they are highly accurate. As always, keep in mind that beta ratings are laboratory measurements under steady flow conditions with artificial contaminants — the real proof of the performance is how clean the filter keeps the fluids in the application. A good oil analysis program that checks the cleanliness of the oil periodically will verify that the proper filters are being used.

Test Dust Size Comparisons

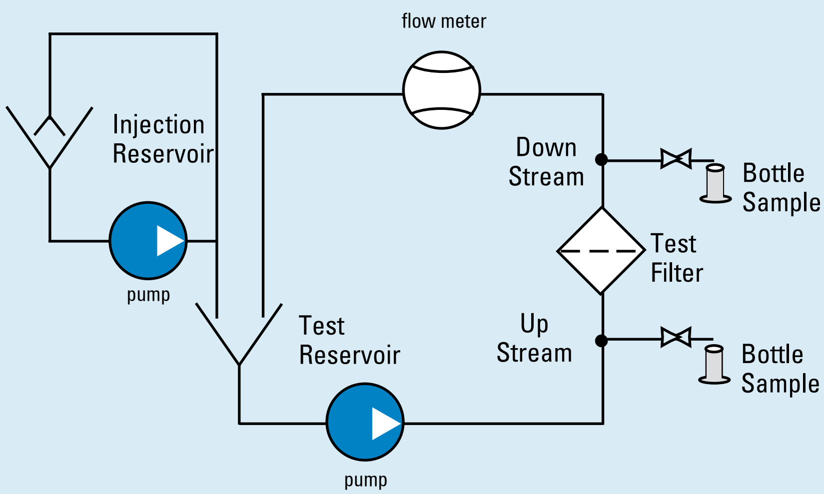
ACFTD calibrated size (µm) per ISO 4402 corresponds to a NIST-calibrated size [$\mu m_{(c)}$] per ISO 11171

ACFTD	0.8	1	2	2.7	3	4.3	5	7	10	12	15	15.5	20	25	30	40	50
NIST	4	4.2	4.6	5	5.1	6	6.4	7.7	9.8	11.3	13.6	14	17.5	21.2	24.9	31.7	38.2



ISO 16889

- In-Line Liquid Automatic Particle Counters (APC) are now required for proper testing.
- APC calibration follows ISO 11171 procedures
- ISO 11171 uses NIST (National Institute of Standards & Technology) certified calibration fluid



ISO 4572

(Discontinued)

- Either bottle samples or APC's were allowed.
- APC calibration followed ISO4402 ACFTD (Discontinued)

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Highlights of ISO 16889

- ISO 4572 is now replaced by ISO 16889 as the international standard for Multi-Pass Tests to determine the efficiency (beta rating or beta ratio) and the dirt-holding capacity of the filter element.
- The test bench for ISO 16889 must have On-Line Liquid Automatic Optical Particle Counters (APC) calibrated using NIST (National Institute of Standards & Technology)-certified calibration fluid. This includes added enhancements to APC's, to allow for better resolution, accuracy, repeatability and reproducibility.
- ISO 12103-1,A3 (ISO Medium, 5mm-80mm) Test Dust was selected as replacement dust for calibration and testing procedures.
- APC's are calibrated by passing a sample of calibration fluid with a known particle size distribution and producing a calibration curve to match the known count distribution.
- NIST used the Scanning Electron Microscope analysis and statistical analysis techniques to certify the particle size distribution.
- Particle counts, upstream and downstream, are taken every minute of the test.
- Beta ratios are reported with (c) to designate NIST traceability.

ISO 16889 recommends reporting beta ratings at:

Rating	*Efficiency*
2	50%
10	90%
75	98.7%
100	99%
200	99.5%
1000	99.9%

Example: $\beta_{4(c)}$ =200 signifies that there are 200 times as many particles that are 4 µm and larger upstream as downstream. This is **99.5% efficiency.**

Example: $\beta_{5(c)}$ =1000 indicates that there are 1000 times as many particles that are 5 µm and larger upstream as downstream. This is **99.9% efficiency.**

Donaldson Hydraulic Filter Media Beta Ratings

Donaldson hydraulic filter media beta ratings are average ratings obtained from multi-pass tests performed per the new ISO 16889 standard.

According to the ISO standard, each filter manufacturer can test a given filter at a variety of flow rates and terminal pressure drop ratings that fit the application, system configuration and filter size. Your actual performance may vary depending on the configuration of the filter tested and test conditions.

NEW Donaldson Filter Media Efficiency Ratings Per ISO 16889 Test Standards

Media Number	**FORMER Rating** $Beta_x$=75 per ISO 4572	**NEW Rating** $Beta_{x(c)}$=200 per ISO 16889	**NEW Rating** $Beta_{x(c)}$=1000 per ISO 16889
Donaldson Synteq® Synthetic Media			
No. ½	2 µm	<4 $\mu m_{(c)}$	<4 $\mu m_{(c)}$
No. 1	3 µm	4 $\mu m_{(c)}$	6 $\mu m_{(c)}$
No. 2	5 µm	5 $\mu m_{(c)}$	9 $\mu m_{(c)}$
No. 2½	10 µm	8 $\mu m_{(c)}$	10 $\mu m_{(c)}$
No. 3	15 µm	12 $\mu m_{(c)}$	14 $\mu m_{(c)}$
No. 4	16 µm	15 $\mu m_{(c)}$	20 $\mu m_{(c)}$
No. 6	13 µm	10 $\mu m_{(c)}$	13 $\mu m_{(c)}$
No. 9	22 µm	18 $\mu m_{(c)}$	23 $\mu m_{(c)}$
No. 16	37 µm	16 $\mu m_{(c)}$	22 $\mu m_{(c)}$
No. 20	40 µm	>50 $\mu m_{(c)}$	>50 $\mu m_{(c)}$
Donaldson Cellulose Media			
No. 3	16 µm	18 $\mu m_{(c)}$	24 $\mu m_{(c)}$
No. 10	25 µm	19 $\mu m_{(c)}$	23 $\mu m_{(c)}$
No. 15	35 µm	25 $\mu m_{(c)}$	29 $\mu m_{(c)}$
No. 25	N/A	32 $\mu m_{(c)}$	>40 $\mu m_{(c)}$
Donaldson Wire Mesh Media			
No. 44	45 µm nominal		
No. 74	75 µm nominal		
No. 149	150 µm nominal		
Donaldson Triboguard™ Synteq Synthetic Media			
DT 2UM	N/A	<4 $\mu m_{(c)}$	<4 $\mu m_{(c)}$
DT 5UM	N/A	4 $\mu m_{(c)}$	5 $\mu m_{(c)}$
DT 8UM	N/A	6 $\mu m_{(c)}$	8 $\mu m_{(c)}$
DT 14UM	N/A	10 $\mu m_{(c)}$	14 $\mu m_{(c)}$
DT 25UM	N/A	20 $\mu m_{(c)}$	25 $\mu m_{(c)}$

Cleanliness Level Correlation Table

Conversion of cleanliness specifications to filter performance is not an exact science because the contamination level in a hydraulic system is a function of the ingression and generation rate as well as the filter performance.

Factors That Affect Cleanliness Levels in a Hydraulic System

- Abrasive wear in space between adjacent moving surfaces of components.
- Erosive wear at component edges or direction changes where there is high fluid velocity.
- Fatigue wear by particles trapped between moving surfaces.

Identification of the Most Sensitive Component

- Required cleanliness level is dominated by the component with smallest clearances and/or highest loading on the lubricating film.
- Best source for determining this level is the specification published by the component manufacturer.
- Higher pressures reduce component life, unless contamination level is decreased accordingly.
- Operating at half the rated pressure of component will increase its life by more than four times.
- Percent of operating time at maximum pressure depends on individual machines and application.

ISO Code	Particles Per Milliliter >10 microns	ISO FTD* Gravimetric Level (mg/l)	Mil Std 1236A (1967)	NAS 1638 (1964)	SAE Level (1963)
30/26/23	140,000	1000			
29/25/23	85,000		1000		
26/25/20	14,000	100	700		
23/21/18	4,500			12	
2220/18	2,400		500		
22/20/17	2,300			11	
21/20/17	1,400	10			
21/19/16	1,200		10		
20/18/15	580			9	6
19/17/14	280		300	8	5
18/16/13	140	1		7	4
17/15/12	70			6	3
16/14/12	40		200		
16/14/10	35			5	2
15/13/10	14	0.1		4	1
14/12/9	9			3	0
13/11/8	5			2	
12/10/8	3		100		
12/10/7	2.3			1	
11/10/6	1.4	0.01			
11/9/6	1.2			0	
10/8/5	0.6			0	
9/7/5	0.3		50		
8/6/3	0.14	0.001			
7/5/2	0.04		25		
6/2/.8	0.01		10		

* SAE Fine Test Dust — ISO approved test and calibration contaminant. Source: Milwaukee School of Engineering Seminar, Contamination & Filtration of Hydraulic Systems

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Compatibility of Donaldson Filter Media with Hydraulic Fluids

While Donaldson has developed many formulations of media, they can be divided into two broad categories: natural fibers, usually cellulose, and synthetic or man-made fibers.

	Recommended Filter Media		
Petroleum-Based (Hydrocarbon) Fluids	Cellulose	Synteq	DT Synteq
Straight oils	Yes	Yes	Yes
ATFs	Yes	Yes	Yes
Military hydraulic fluids	Yes	Yes	Yes
#2 Diesel fuel	Yes	Yes	Yes
Gasoline	Yes	Yes	Yes
E85 (85/15 Ethanol/Gasoline)	No	No	Yes
Fire Resistant Fluids	Cellulose	Synteq	DT Synteq
HFA - Oil-in-water emulsion	No	<150°F	Yes
HFB - Water-in-oil emulsion	No	<150°F	Yes
HFC - Water glycol	No	<150°F	Yes
HFD Synthetics - Polyol esters, Esters, Diesters, & blends	No	Yes	Yes
HFD Synthetics - Phosphate esters	No	No	Yes
HFD Synthetics - Polyalkylene glycols (PAG), Polyalphaolefins (PAO), & blends	No	Yes	Yes
HFD Synthetics - Silicone (siloxane) oil	No	Yes	Yes
Biodegradable Fluids	Cellulose	Synteq	DT Synteq
Vegetable-based oils - sunflower, rapeseed oils	No	Yes	Yes
Synthetic oils - PAG / PAO	No	Yes	Yes
Synthetic oils - Esters, Diesters	No	Yes	Yes

Piston Pump Damage

The severe score marks on the piston slippers leave no question about why good hydraulic filtration is important.

A Note on Seals

- Filters with seals made of BunaN are appropriate for most applications involving petroleum oil and some high water content fluids. Filters with seals made of Viton® or Fluorel® (both fluoroelastomers) are required when using diesters, phosphate ester fluids. Donaldson offers both types. (Viton is a registered trademark of DuPont Dow Elastomers, and Fluorel is a registered trademark of 3M Company.) EPR (ethylene propylene rubber) seals are required for use with Skydrol® and Skydrol 500 fluids. (Skydrol is a registered trademark of Solutin, Inc.)
- In Donaldson filters with fluorocarbon elastomer seals, epoxy potting is used to accommodate higher temperature environments and for compatibility with fluids such as phosphate ester, diesters, and high water based fluids. The plastisol (heat cured) and urethane (self curing) potting materials used in other filters perform well with petroleum-based fluids.

How to Best Position Filters in Your Hydraulic Circuit

Within every industrial hydraulic circuit there are many possible places for filters.

The best systems are strategically engineered to ensure that oil is filtered properly at each stage of its journey through the circuit. Ideally, filtration should occur in the following places:

- In the Reservoir
- Before/After the Pump
- In the Return-line System
- Off-line

In reality, many companies have to make tough decisions about which filters they can afford and which ones they'll have to live without.

Much depends on the cleanliness level requirements of the components, environment, duty cycle of the equipment and other variables that can vary from application to application.

Portable Kidney Loop Filter Cart

Kidney Loop Filters

Benefit: High

Sometimes referred to as "off-line" filters, kidney loop filters achieve very fine filtration by maintaining steady-state flow, independent of the hydraulic circuit.

With this type of filtration, the entire hydraulic system can keep operating while the kidney loop filter is being serviced.

A kidney loop filter utilizes low-pressure housings that are easily accessible and serviceable. These filters can either be integrated into the main hydraulic reservoir, or used in mobile filter carts like the one shown at left to service many hydraulic systems.

Note that kidney loop filters do not directly protect components — rather, their main function is to polish the oil to a very clean condition. It's also important to remember that an additional pump and motor will be required.

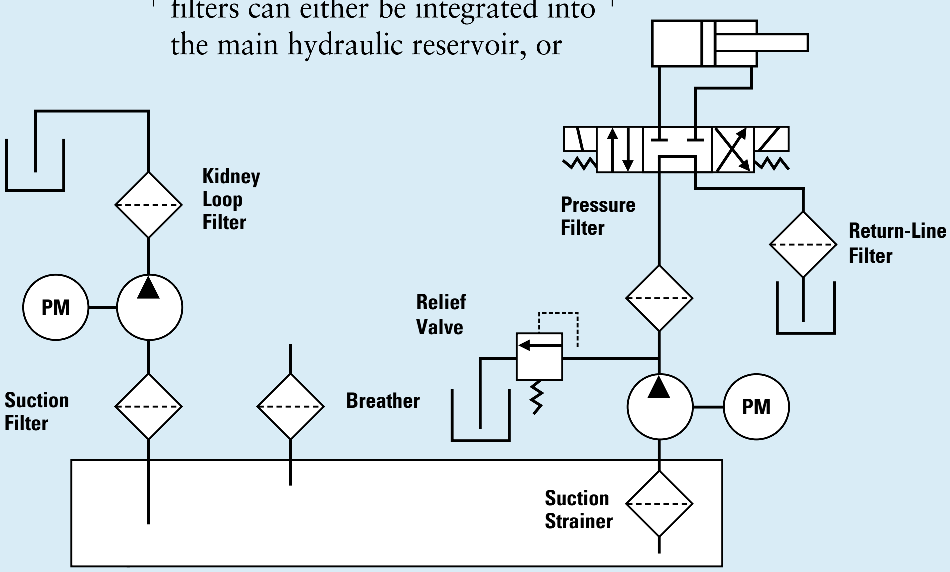
Filler / Breather

Benefit: High

Tank breathers are placed on hydraulic reservoirs to prevent atmospheric contamination from entering and to allow for sufficient air movement inside the reservoir.

Breathers should prevent particles larger than 3 microns from entering the system. This is a sensible, affordable solution for any hydraulic system, but by all means cannot be the only filter on a hydraulic system.

This diagram shows how various types of filters can be used in hydraulic circuits.



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Suction Filter
Benefit: Medium

Normally placed between the reservoir and the pump, suction filters are designed to remove particles in the 5 to 150 micron range. They are easier to service and less expensive than many other types of filters—but because restriction in the suction line must be kept very low, filter housing size tends to be larger than similar flow return or pressure filter housings.

The most popular application for suction filters is with variable-speed hydrostatic pumps commonly found in off-road mobile applications and industrial variable-speed drives. They are also often used in harsh environments and charge pump applications.

Suction Strainer
Benefit: Low

Suction strainers, or sump-type filters, are often used in hydraulic fluid reservoirs. Their only real use is to keep cigarette butts, moths, nuts & bolts and the like out of the pump. Instead, such contaminants can easily be eliminated by keeping the reservoir sealed and by using a Filler/Breather and Return-Line Filter.

Return-Line Filter
Benefit: High

The advantages of return-line filters are many. They are usually low-pressure housings, which are less typically expensive. Their purpose is to collect the dirt from around the circuit as the oil returns to the reservoir. Much like the kidney loop, the return-line filter provides

ultimate flexibility in positioning—it can perform almost anywhere within the return line circuit, either mounted inline or built into the reservoir.

Downsides are few, but worth noting: return-line filters can be subject to flow surges (which contribute to poor filter performance) and they do not filter the drain lines.

Note regarding return-line and kidney-loop filtration: If you're looking for a great value filter that's easy to maintain and with lots of media choices, this is a wise investment. Although these filters are very common, one downside is that there are very few standards of consistency from one manufacturer to the next, so replacement cartridges are not necessarily interchangeable.

Pressure Filter
Benefit: High

This is also known as "last-chance" filtration. High pressure filters keep clean the oil that comes directly from the pump so that the more expensive downstream components (such as valves and actuators) are protected. Pressure line filters offer protection from catastrophic pump failure. They are a worthwhile investment for high-value systems — as are found in the aircraft industry, paper and steel mills, plastic injection molding, and in die-casting machines.

One downside to high pressure filters is, ironically, the high pressure. The entire system must be stopped in order to service a high-pressure filter—unless a duplex configuration is used. When oil is shooting out of a pump at 6000+ psi, it will take out anything in its way! By nature, a high-pressure pump is a prime mover of fluids, so it will experience significant wear over time. Service can also be more difficult because of its heavy-duty construction—as anyone who's ever tried to change a slippery, 200-pound cast-iron filter can attest.