

All about Oil Filters

By Mark Lawrence

I am not a lubrication, filtering, chemical or mechanical engineer. I have a degree in engineering, but I studied electrical engineering. I now study physics. You may feel free to question my abilities to gather facts and draw conclusions in the area of oils and filters. In any case, this is a write up of what I learned in about 30 hours of research on this topic. If your eyes glaze over in science classes and you simply wish there were someone with a science background and no financial interest in oils and filters who would do all the leg work for you, I'm your guy. My only interest is having my motorcycle run forever, never break, and be easy to maintain.

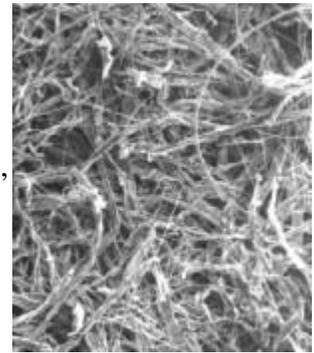
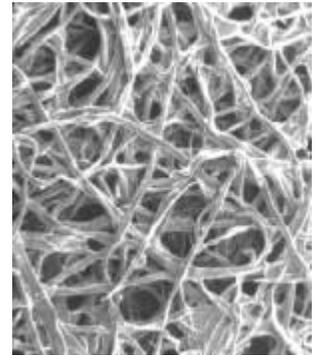
Oil Filters come basically in three qualities. Very good, with excellent filtration; normal; and really incredibly bad. This last category, really incredibly bad, should obviously be avoided. Accordingly, never use a Fram, Pennzoil, Penske, Castrol, or Quaker State oil filter in any motor you like. All of these filters are made by Fram. The filter element itself is a normal paper element, and probably no better or worse than anyone else's paper element. However, the end caps on the filter element are made of cardboard in these filters. There are numerous stories of these cardboard end caps getting saturated with oil and coming apart, putting little cardboard fragments directly into the oil flow into your engine bearings. As they say in GhostBusters, this "would be bad." Personally, I don't consider cardboard a suitable material for my engine internals. In the interests of fairness, below I reproduce a letter from Fram to me.

An interesting question is; do oil filters really do anything useful at all? Of course, conventional wisdom is your bike would simply die a horrible death in about 3 minutes without a filter. But, we've all had the experience of making the first oil change on a new engine: the oil comes out looking like oil-colored metal flake paint. Here's the interesting question: why didn't the filter catch all those flakes? If the OEM filter is so great, how come it visibly didn't clean the oil of this very obnoxious crud? I can only think of two possibilities: either the filter let the metal flakes through, which is quite disconcerting, or the filter became completely clogged up in the first 20 miles or so, and I was running with the bypass valve activated ever since - effectively running without any oil filter at all. This is my motivation in searching for better filters. Also I consider it my duty as an American male to supply ammunition for women to say "If you treated me half as well as you treat that stupid motorcycle, we'd never have any problems!"

The single most interesting piece of information I could give in this article is filtering efficiency versus particle size for all the popular filters. I don't have it. You can get this information for any other filter you wish to buy, but most automotive oil filter companies simply don't release this information. So we're going to have to make our decisions with insufficient data.

Filter Elements

Most oil filters have filter elements made of paper and are effective down to about 40 microns. To the right is a paper element expanded 50 times. In this picture, a 30 micron particle is about this big: o. The advanced filters have composite elements made of paper, cellulose, and fiberglass, and are effective down to 15 microns or less. Typically these advanced filters also have more surface area on their elements, and therefore more capacity. To put this into perspective, 25 microns is about 1 thousandth of an inch. In your motor, most parts like pistons, bearings, and bushings are set up with a clearance of 1 thousandth of an inch, so to the moving lubricated parts a 25 micron particle is as big as the oil film, and will scratch both surfaces. We don't want anything in our engines that is 25 microns or bigger. Some companies claim that even particles as small as 1 to 5 microns cause premature engine wear, but I don't find the evidence on this topic to be compelling, either for or against. Anyway, you can see now that standard paper filters are marginal. The paper filters let through about 10 to 20 times as much 25 micron stuff as the synthetic filters do, and about 5 to 10 times as much 15 micron stuff.



To the right is a synthetic element expanded 50 times. It's not enough to ask a company to what size particle their filter is effective. Imagine a screen door with some oil on it. Obviously something the size of a golf ball or fly is simply not getting through. However, even particles which are a tenth the size of the holes sometimes don't get through - spray your screen door with a garden hose and see what comes off. Oil filters are similar, except the holes are random in size, not perfectly regular like a screen door. So, company A says "Our filters are effective down to 7 microns." What does this mean? If "effective" means "we catch 15%," well, I'm not impressed. You need an efficiency number along with the size number before you can really think you know something. No filter is 100% effective - this would require either very regular holes, which are currently impossible to mass produce, or very small holes on average, which would block too much oil flow.

Purolator makes filters in three qualities, standard, premium, and Pure One. Purolator states that their premium filters capture 97.8% @ 30 microns and 85.2% @ 20 microns. These numbers are typical of a normal paper element oil filter. The Purolator Pure One filters capture 99.8% @ 30 microns and 99.2% @ 20 microns. This means the Premium filter is letting through eleven times as many 30 micron particles as the Pure One, and eighteen times as many 20 micron particles. Clearly, the Pure One filter is doing a considerably better job of cleaning the oil than the premium filter.

The way the Pure One achieves this filtering efficiency is by combining three different types of materials in their filter: paper like everyone else to catch the big stuff, and cellulose and fiberglass fibers to fill in the "large" holes in the paper with their much finer fibers. Filters like this are now made by Purolator, Hastings (marketed as AMS), and Champion (marketed as Mobil 1 and Bosch). Accordingly, the best oil filters are the Purolator Pure One, Mobil-1, AMSOil, and Bosch. If you use one of these filters with one of the commercial synthetic oils listed above, you have the best protection money can buy.

Champion says the Bosch is a 15 micron filter, and the Mobil-1 is a 10 micron filter but gives no efficiency numbers. AMS claims their filter is effective to "7 to 10 microns," but again without any efficiency number. Fram makes a new filter, the X2, which they claim is in this category, but I'm skeptical of all things Fram. In particular, in the letter below you will see that a Fram employee seems to indicate

that all Fram filters have a rating of 10 microns, which calls into serious question how they measure their paper filters, and also why one would pay three times as much for their advanced filters given that they have the same rating as their basic filters. SAE tests would tend to indicate that the Purolator has a slight advantage in filtering over the other filters named here. The important thing is, all of these filters have performance at 30 microns which is far superior to a paper only filter, and all of these filters have performance at 20 microns which is also far superior to a paper filter. So, bottom line, these filters will clean your oil far better than a paper-only filter.

Of these five filters, only the AMS is specifically recommended for motorcycles, the rest are car filters. If you call the tech support people (I have) and ask what the difference is, you will likely not get a meaningful answer. I certainly didn't. I don't imagine that Honda makes special low-quality oil pumps just for their water-cooled 100 hp/liter four cylinder motorcycle engines, as opposed to their water-cooled 100 hp/liter four cylinder car engines. Maybe 30 years ago Triumph and Harley made suspect oil pumps with strange characteristics and we're still living down some old mythology. Maybe the filter companies don't want legal exposure in the US to a very small group of customers who often use their engines like they're in the Daytona 500. Maybe Honda wants you to buy their mass-marketed paper filter for \$12 instead of buying a mass-marketed paper filter from Wal- Mart for \$2. If you think Honda car engines are completely different from Honda motorcycle engines, go drive an S2000. Lemme tell you, it's a 4-wheeled motorcycle. Tons of fun, too.

All filters have to undergo SAE (Society of Automotive Engineers) tests to prove that they meet the engine manufacturer's requirements. The SAE J806 test uses a single-pass test, checking for contaminant holding capacity, size of contaminant particles trapped, and ability to maintain clean oil. As an amendment of the J806 test, the multi-pass test also looks for filter life in hours, contaminant capacity in grams, and efficiency based on weight. The efficiency of the filter is determined only by weight through gravimetric measurement of the filtered test liquid. Typical numbers for paper filter elements are 85% (single pass) and 80% (multi-pass). A new test, the SAE J1858, provides both particle counting and gravimetric measurement to measure filter capacity and efficiency. Actual counts of contaminant particles by size are obtained every 10 minutes, both upstream (before the filter) and downstream (after the filter), for evaluation. From this data filtration ratio and efficiency for each contaminant particle size can be determined as well as dust capacity and pressure loss as a function of time. Typical numbers for paper element filters are 40% at 10 microns, 60% at 20 microns, 93% at 30 microns, and 97% at 40 microns. This means a paper filter passes about 25 times as many 30 micron particles as a Pure One. I would love to see these numbers for the various available filters, but no one seems to be talking.

There's a new type of filter being marketed, the "laser cut stainless steel filter," which we're told is "good for the life of your vehicle."

These filters typically have 35-40 micron holes, which is really not acceptable. They typically have 30-40 square inches of filter material, which is really not acceptable. A paper based element is a 3 dimensional filter - when a particle gets stuck deep in the filter element, oil can still flow around it. The stainless steel elements are 2 dimensional - when a particle gets caught, one of the holes is clogged up. I don't see how you can assure that all the holes get cleared out when you clean these. Certainly simply soaking the filter in kerosene is not going to release particles that have been jammed into a hole at 60psi. Blowing the filter out with air sounds good, but a motorcycle filter is too small to let an air hose inside. These stainless steel filters cost about \$120, about 25 times what I pay for a Pure One.



Since I use my filters for about 8,000 miles, that means I have to go 200,000 miles to break even. I've never put more than 60,000 miles on a vehicle.

I don't think this technology is ready to use yet. When the holes get down to 20 microns, and the surface area up to about 100-150 square inches, then I think I'll consider using one. Meanwhile, "good for the life of your vehicle" is not an impressive claim if the device shortens the life of your vehicle.

Another interesting filter is the CM Racing filter. I don't actually know anything about it. It does look interesting.

Filter drain back & Bypass valves

Filters also have relief or bypass valves. These valves are set to trigger if the filter element is making too

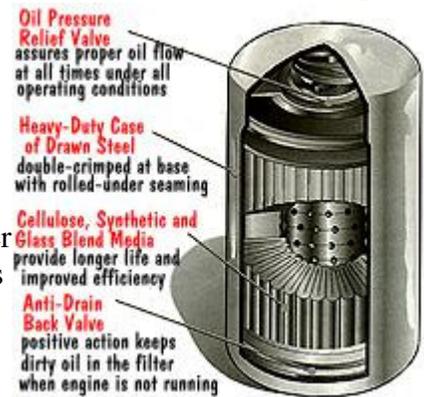
large a pressure drop. Normally, this would be because it is clogged, however on an engine with a very high flow oil pump this can also happen if the oil is very cold. Motorcycles do not have high- flow oil pumps. These relief valves are set for different pressures, and

sometimes a tech or mechanic will tell you that it's important that the relief valve have the correct rating. It's not. These valves are very low-precision devices, and their pop- off values are different from each other even in identical filters of the same brand. I have spoken with engineers (not techs) at AMS, Purolator, Mobil, and Champion, and not one of them knows of a single reason why you can't use a car filter on a motorcycle. In fact, not one of them could quote me a single pop-off valve pressure rating off the tops of their heads. They did not consider

this an interesting or important topic until I brought it up. When the relief valve is open, the oil is going around the filter element and not being filtered at all. If your relief valve ever opens up you're either using a really cheap oil on a really cold day, or you haven't changed your oil filter since the last time you saw Robert E. Lee. Because filters can clog up and saturate with junk, your oil filter should be changed about every 5,000 miles. In fact, if you are using an advanced synthetic oil, you should probably change your oil filter about twice as often as you change your oil.

Finally, some oil filters come with an anti- drain back valve. This is not necessary in a filter which is mounted vertically, with the opening pointed up. However, most motorcycles mount their filters horizontally, so this is very important to us. This is typically a piece of nitrile or silicon rubber which blocks off the filter oil inlets unless there is positive pressure into the filter. After you have used a filter for a while, if it's doing it's job, the filter is full of these 20 to 50 micron particles which mean death for your bearings. If you were to ever run the oil through this filter backwards, these particles would be released into the engine almost all at once. This "would be bad."

When you turn off your engine, if the filter has no anti-drain back valve, whatever oil is in the filter will drain back into the oil pan, bringing with it a whole bunch of really evil junk. So, we want filters with good anti- drain back valves: the stuff that's in the filter should stay in the filter. To the right is a picture of the Pure-One and the Mobil-1 anti-drainback valves. Both filters use the superior silicon rubber. The Pure-One has a larger core and a convex shaped mating surface to guarantee an excellent fit. The Mobil-1



has a flat seal and a flat mating surface which do not inspire the same confidence. The Mobil-1 anti-drainback valve is in turn clearly superior to that of most other filters. The people linked below who dissected many oil filters found that some brands have a really cheap piece of plastic that doesn't seal very well. The filters I have listed as top rated all have good anti-drain back valves.

I received an email from Suzuki of Victoria, informing me that a Hayabusa they took in for service showed no oil pressure. They found the cause was an aged anti-drainback valve on a Hi-Flo filter that would not open, thus cutting off all oil pressure to the entire engine. K&N filters are made by Hi-Flo, so these filters are also suspect.

Jon Satterfield purchased and dissected several filters for Honda Motorcycles. We all owe him a big debt of gratitude. Here's his results:

Filter	Surface area Sq.In.	Filter Thickness	Relief Valve PSI	Case Thickness	Drainback Valve	Comments
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- AMSOil - SMF 103 36 .038 25 10 mil nitrile
Internally contaminated with dirt particles when new. Excellent filter media, but not much of it.
- Bosch - 3323 82 .038 25 20 mil silicon
Very good filter media, similar surface area to stock filter.
- Mobil-1 M1-110 60 .038 25 20 mil silicon
Excellent filter media, but only 2/3 the surface area of a stock filter.
- Pure One - PL14620 110 .030 17 20 mil silicon
Excellent filter media, and there's a bit more of it than stock.
- SuperTech - ST6607 41 .023 18 10 mil nitrile
Comparable to an OEM filter, but \$2 instead of \$13.
- Toyo Roki - OEM 94 .035 18 20 mil nitrile
Decent filter media - not up to the standards of the Purolator, Mobil-1, or AMSOil, but there's a lot of it.

Recommendations

I recommend a Mobil-1 M1-110 or Purolator Pure One PL14620/PL14610. These filters stand out from all the alternatives as having superior filtering, excellent construction, and they're widely available at a reasonable price. I use the Pure One - it's half the price, and somewhat better due to having almost double the filter surface area. The AMSOil has superior filtering, but I cannot recommend it due to the exceptionally small amount of filter surface area. In 7/03, Purolator is obsoleting the PL14620 and superseding it with the new PL14610.

All this should be understood within the context of your owners' manual: Honda recommends a normal paper filter, changed every 8,000 miles, and normal petroleum oil, changed every 8,000 miles. My recommendations are far more conservative than theirs. It's worthwhile to consider the practices of long-distance diesel truck owners. These guys keep careful records and in the large companies like Penske routinely do oil analysis. The normal practice on a diesel engine is to change the filter every 15,000 miles. Oil changes are typically every 15,000 miles for petroleum based oils like Rotella T or Delvac 1300, or every 50,000 to 150,000 miles for synthetic oils like Rotella Synthetic or Delvac-1. Now, before you get all excited about the possibilities, you must also keep in mind that the diesel engines don't run their oil through their transmission, and the large diesels all have two oil filters, one a normal paper filter, and the other a 1 or 2 micron filter that catches pretty much everything. We don't

have these secondary ultra-fine oil filters on our bikes. Also, the large diesel engines hold eleven gallons of oil - a oil and filter change costs these guys \$350 if they use synthetics, \$150 if they don't.

You can do your own research on oil filters by reading my own study of filter construction, “A superlative study of filter construction and performance”, SynLube's introduction to filtering oil, and Mike Guillory's survey of filters. Todd Marcucci takes apart a bunch of Honda Prelude filters, and learns that Honda car filters in N.America are junk. Toby Creek applies surgical techniques to oil filters, Russell dissects a bunch of filters, and Russell does yet more dissection. Perf-Form sells advanced media filters.

Oil filter manufacturers:

- AMS oil
- Champion Labs
- EMGO
- Fram
- Denso
- Hastings
- Hi Flo
- K & N
- Perf-From
- Purolator
- Toyo Roki
- Veshra
- Wix

A Letter from Fram

Mr. Lawrence:

Thank you for the e-mail regarding the construction and micron rating of Fram oil filters. We welcome the opportunity to be of service.

Fram filters meet the requirements of the original equipment filter designed for a specific engine. Our filter applications follow the recommendations of the vehicle manufacturer for form, fit, and function. Fram filters follow internally targeted design guidelines to meet the functional requirements of a given filter. Fram filters are tested against SAE standards to ensure uniform product quality and performance. Material construction will vary between filter manufacturers. We believe Fram filters have a proven record for providing reliability, superior quality, and engine protection over the service life of the filter. A common misunderstanding among our customers concerns the end disks in the oil filter. These disks hold the glue which keeps the pleated media formed into a rigid circular tube. The glue-to-media interface is also one of the sealing surfaces keeping dirty and filtered oil from mixing. One common myth is that only metal end disks can adequately seal and have enough strength in the hot oil environment. For this reason, Fram filters are criticized for having cardboard end disks. The issue is, the material doing the sealing is the adhesive, regardless of the material of the end disk. What matters is the strength of the adhesive, its proper curing, the thoroughness with which it can be applied to the disk, and its adhesion to the disk. By using cardboard end disks, Fram filter engineers are able to specify adhesives with excellent strength and sealing properties, and strong adhesion to the disk (intuitively, it is easy to make a strong glue bond with cardboard). Moreover, just as paper media itself is able to withstand the hot oil environment, so too is the end disk designed of fibers engineered to be strong and

inert in hot oil. The thickness and strength of the adhesive also stiffens the end disk considerably. Fram engineers perform hot oil circulation tests on the filter element and also regularly cut open used filters to examine how well they have withstood the rigors of actual use on a vehicle. For over 38 years, Fram end disks have stood up to hot oil and their adhesives have sealed off the dirty oil.

Fram's latest entry in the automotive oil filter market is the X2 Extended Guard oil filter. The Fram X2 Extended Guard filter uses a filter media that includes a reinforced mesh screen for maximum pleat integrity, durability, and oil flow. The inclusion of the metal screen increased the glue tolerances or thickness required for proper adhesion to the end disk. The original X2 prototype development specified the cardboard end disk technology. However, the increased amount of adhesive required to join the cardboard end disk to the screened media resulted in prototypes that did not conform to design standards. We had no choice but to use a steel end disk with the X2 filter media to provide uniform Extended Guard oil filter construction.

Fram automotive oil filters, including the standard Extra Guard and premium X2 Extended Guard filters, have a micron rating of 10 micron.

If you require further assistance with Fram filter construction, please contact the Fram Engineering Department directly at 1-419-661-6700.

Thank you for your interest in Fram filters.

Cordially, Scott Jacobs, Catalog/Technical Service Representative