Questions & Answers

On

Bypass Microfilters

Economic, Environmental, & Microfiltration
Technology Information

"Clean Oil Reduces Costs & Builds Sustainability"

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Reduce Costs

What is a Microfilter?

A HEPO Filters® microfilter is a high efficiency engine lubrication oil filter device, which is added to the engine to remove hard physical micro contaminants, referred to as Clearance Level Particles, "CLP." These physical contaminants typically range from 2 to 25 microns in size.

How Does a Microfilter Reduce Costs?

Removing CLP from the oil means greater lubricity, less friction, less engine wear, and allows the oil to reach its full useful life. Cost savings come directly from reducing engine friction and wear over the lifecycle of the asset and from extending the oil drain interval to take advantage of clean oil's longer useful life.

What is the HEPO Filters® Return on Investment?

The ROI is generally less than one year. Typically, it pays for itself in 4 to 6 oil changes, depending on service duty and other oil service costs. The ROI ranges from 3 months down to a year. The cost savings range from approximately $600 per year to $1,500 per vehicle.

How Can I Determine the ROI for Our Fleet?

HEPO Filters provides fleet savings projections without charge. Please contact us and we will provide a fleet cost savings and analysis based upon your specific equipment and service duty.

What are the Operational Benefits?

A fleet can reduce approximately 2/3rds of their oil services. This allows for a more efficient operation. Some shops have re-adjusted the maximum/minimum schedules on the PM to reduce a "pit trip". This improves facility utilization and allows mechanics to work on higher priority maintenance issues. The vehicle will likely still follow its monthly service but less time will be required on oil service and can be redirected to higher value items.

Will Microfilters Reduce Costs in Natural Gas and Diesel Engines?

Yes. HEPO Filters microfilters will reduce costs in any engine, including Compressed Natural Gas (CNG), Liquid Natural Gas (LNG), diesel, gasoline and alternative fuel engines. Modern engines operate at higher combustion chamber temperatures and at closer tolerances. The closer tolerances require cleaner oil, free of CLP contaminants. The benefit of keeping the oil clean to get the full useful life from the oil is universal.

Do Microfilters Reduce EGR Lubrication Costs?

Yes. Exhaust Gas Recirculation (EGR**)** is a NOx (nitrogen oxide and nitrogen dioxide) reduction technique used in most gasoline and diesel engines. The engine tailpipe exhaust will discharge less soot into the air and reduce NOx; however, there is a trade-off. Some soot will be pumped into the lubricating oil, causing more soot to get into the crankcase. This will require larger sumps and/or more frequent oil changes. Microfilters are ideally designed to remove the higher levels of soot in EGR engines, producing major cost savings by keeping the oil cleaner, longer.

What Types of Microfilters Does HEPO Filters Provide?

HEPO Filters provides microfilters, which will clean engine lubrication oil. We offer two product lines, our standard OilGuard product line, which doubles the oil drain interval, and the advanced filtration HEPO devices, which provide absolute filtration[1] throughout the 2 to 25 micron size range. Due to its high level of filtration, the HEPO product line is guaranteed to triple the oil drain interval and provide fuel savings of 2% or more.

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[1] The Filter Manufacturers Council, *Technical Service Bulletin 89-5R3*, defines "Absolute" filtration as achieving an efficiency of 98.7% or higher at the stated size.

Reduce Engine Wear

Is Engine Wear Inevitable?

Yes. The *rate* of engine wear, however, can be dramatically reduced if Clearance Level Particle contamination is reduced. Cleaner engines require fewer engine overhauls, which means reduced maintenance costs even if the Life Cycle is much less as in a fleet that turns over the assets much more quickly.

Why is there Growing Awareness about Clearance Level Particles?

Modern engines have closer tolerances than the early engines, so the oil film must be cleaner to avoid the same friction and wear. Today's oils are much better, however, today's engines produce much more stress on the oil with tighter tolerances, increased soot production and higher heat.

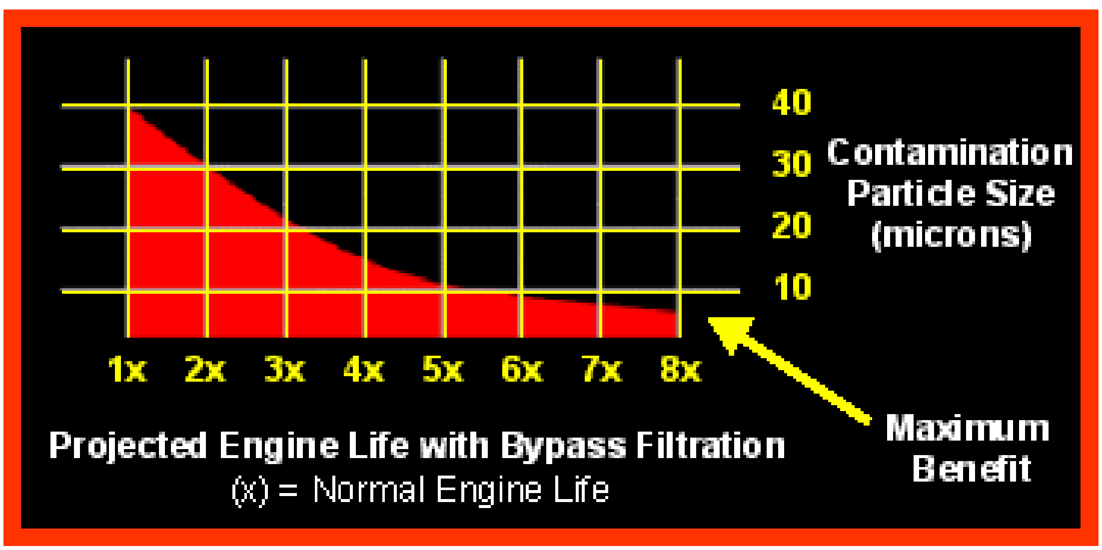
Can you provide an Example of Life-Cycle Savings?

Yes. City transit buses usually have a life cycle of 12 years or more. In some instances, a twelve-year minimum retention is required when a governmental agency provides equipment acquisition funding. During a twelve-year life, one or more engine overhauls is required depending on the type of equipment, service duty and other conditions. The cost for a new engine or full overhaul on a diesel engine is $12,000 to $25,000 and on a low-emission transit CNG engine is $30,000 or more.

What is the Relationship between Particle Contamination and Engine Wear?

General Motors published the leading study on the relationship between particle contamination and engine life. The baseline engine life is "1X" at oil that is clean to approximately 40 microns. This is about the lowest level where the full-flow filter can provide absolute filtration. When filtration is increased down to 5-7 microns, engine component life can be extended seven to eight times longer.

Figure 1 General Motors SAE Technical Paper Series # 881825



GM Study - Influence of Filtration on Engine Wear[2]		
Filter (micron rating based on 98% single-pass efficiency)	Normalized Wear	Relative Engine Life
40 microns	*1*	*1*
15 microns	0.29	3.4
8.5 microns	0.18	5.5
7 microns	0.14	7.1

HEPO Filters'® remove particles contaminants from 2 to 30 microns at absolute efficiency as measured by Fluid Technologies, Inc., using the SAE J1858 Filter Element Multi-Pass Test.

What are Wear Metals?

As engines operate they shed small amounts of wear metals into the oil. Three of the primary metals used to build engines are aluminum, iron, and lead. Hence, as the engine wears, small amounts of aluminum, iron and lead build up in the oil. The presence of the CLP abrasive slurry of insoluble hard particles accelerates wear and friction, which causes more wear metals to enter the lubrication oil.

Will the Wear Metal Rate Decrease with Microfiltration?

Yes. HEPO Filters microfilters decrease the per mile rate of wear metal production. In one controlled test on twenty-five transit buses, the rate of wear metal production in buses equipped with HEPO Filters microfilters was reduced to approximately half the rate per mile of wear metal production produced in the control buses without the microfilters. The findings confirm the GM report that reducing particle contamination will reduce engine wear.

[2] This chart reprinted with permission from Noria Corporation.

Build Sustainability

What are the Eco-System Benefits of HEPO Filters® Microfilters?

1. Reduce fuel consumption by 2% or more
2. Reduce greenhouse gases, such as carbon dioxide, $CO_{2,}$ by burning 2% less fuel
3. Increase "Source Reduction" of hazardous used crankcase oil by 65%
4. Increase conservation of lubrication oil by 65%
5. Improve air quality by reducing tailpipe emissions by burning less fuel
6. Extend engine life and reduce engine rebuilds

How do Microfilters Produce Environmental Benefits?

HEPO Filters® microfilters remove abrasive "Clearance Level Particles" ("CLP") from the crankcase oil. CLP are physical contaminants, generally from 2 to 25 microns in size. CLP form an insoluble slurry of hard micro-particles within the crankcase oil, which is carried by the oil film between the engine's moving parts. These hard particles scrape and grind against the parts, causing friction and wear. CLP enter the ring-to-cylinder clearance, the rod and shaft bearings clearance, piston bushings and other areas lubricated by the oil. Removing CLP contaminants reduces friction, reduces engine wear, improves fuel economy, extends the life of the engine and the lubricating oil, reduces hazardous waste oil, and conserves engine oil. All these benefits "Green" the fleet, produce major economic savings, and help build sustainable communities.

What Impact do Greenhouse Gases Have on Global Warming?

The Intergovernmental Panel on Climate Change (IPCC) reports that most of the global warming of the Earth's atmosphere observed since the mid-20th century has been caused by human created increases in greenhouse gases, especially carbon dioxide, $CO_{2.}$ Burning fossil fuels accounts for about 75% of the increase in CO_2 over the past twenty years, such as the fossil fuels burned by automobiles, cars, trucks, and buses.

Can Microfiltration Help Reduce Greenhouse Gases?

Yes. Microfiltration keeps lubrication oil cleaner, which reduces friction and wear in the engine's moving parts. Reducing friction increases fuel efficiency by approximately two percent (2%) or more. Burring less fuel reduces carbon dioxide, CO_2, and air particle emissions.

How Do Microfilters Reduce Air Pollution?

The greatest source of air pollution is from vehicles, such as automobiles, trucks, buses, and construction equipment. These vehicles produce chemical and particulate matter (PM) air pollution. In California, the EPA has designated several large areas as "non-attainment zones" for one or more pollutants. Microfiltration improves engine efficiency, improves fuel economy by 2%, which reduces the amount of pollution discharged by engines by 2% or more. Also, some research indicates that cleaner lubrication oil can reduce PM emissions.

Can Microfilters Reduce Hazardous Waste?

Yes. Microfiltration achieves a 65% source reduction of hazardous waste oil.

Why is Source Reduction Important?

The *Pollution Prevention Act of 1990*, US Code 42, Chapter 133, states that "Source reduction is fundamentally different and more desirable than waste management and pollution control… The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible…." Recycling hazardous materials, such as crankcase oil, toxic industrial waste and chemical waste, is fundamentally more costly and complex than recycling non-hazardous materials. In California, used crankcase oil is classified as a hazardous material.

How much is the Source Reduction of Hazardous Used Oil?

HEPO Filters® increase source reduction by 65% or more. The amount of source reduction depends on the amount of engine oil and the number of times the oil is changed per year. As an illustration, in a fleet of 100 transit buses with 12 oil changes per year and 9 gallon engine sumps, the reduction would be approximately 71 gallons per bus and 7,100 gallons per year for the fleet.

How Much Conservation of Engine Oil is Achieved?

HEPO Filters® increase conservation of lubricating oil resources by approximately 65%. One of the benefits of source reduction of hazardous waste oil is that it also reduces consumption of fresh lubricating oil.

The Benefits of Clean Oil[3]

Why Are Oil Filters Necessary?

No lubricating oil can "clean itself." No lubricating oil, whether formulated as synthetic oil or derived from virgin crude mineral oil, can filter out the abrasive physical contaminants. While lubricating oil dispersants and other additives can keep the hard particles in suspension within the oil film, no oil can physically remove the hard contaminants from the oil film. Keeping particle contamination suspended in the oil film cannot prevent wear when the hard particles are forced between the engine's moving parts and scrape or drag against the moving parts.

How Do Particle Contaminates Enter the Oil?

There are three basic sources of particle contamination: 1) The engine, 2) "Fresh Oil," and 3) The air.

What Particle Contaminates Are Produced by the Engine?

Engine friction caused by the movement of engine parts produces wear metal particles. The higher the friction, the higher the rate of particle contamination released into the oil film.

Does Fresh Oil Have Particle Contamination?

Yes. To the naked eye, the clear, yellowish-green or golden-brownish oil looks clean. Since the lower limit of human vision is 50 - 70 microns, the harmful 2 to 25 micron "microgrit" is not visible. Also, there are no oil cleanliness specifications required by engine manufacturer (ISO Code) and oil companies do not report their oil cleanliness. Only special lubrication applications, such as NASA equipment, require clean oil:

> "Contrary to poplar belief that "fresh" oil" is clean, new oil is often very hazardous. It may ship dirty from the supplier, becomes contaminated in storage, or become contaminated during transport to the machine." (*Oil Analysis Basics*, Drew Troyer and Jim Fitch, Revised 2001, Noria Corporation, page 19.)[4]

What Types of Particle Contaminants are in the Air?

According to Troyer and Fitch, many small micron particles are in the air. The authors state that air particles often are harder than the metal parts in the engine – harder than a hacksaw blade, which is harder than engine parts. The first defense from air contaminates entering the lubrication oil is a good quality air filter and good engine seals. However, even with these precautions, some air-borne contaminants will enter the lubricating oil. The second defense is microfiltration to remove the hard particles as they enter the oil.

When are Oil Changes Required?

Oil changes are required when: (a) particle contamination builds up in the oil, or, (b) foreign liquids contaminate the oil (such as fuel or antifreeze), or, (c) when the oil no longer is chemically viable (viscosity out of range, high oxidation, etc.)

What Happens if the Full-Flow Filter Clogs?

If the full-flow filter clogs, a safety valve takes it out of the circuit to prevent catastrophic engine failure from loss of lubrication. This, of course, means that now there is no oil filtration, unless the engine has a microfilter, which operates independently of the full-flow filter.

How Do Clearance Level Particles Reduce Engine Efficiency?

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[3] This copyrighted "Q & A on Particle Contamination" is used with permission from HEPO Filters, Inc.

[4] This quotation of copyrighted material is used with permission of Noria Corporation.

CLP increase friction, which reduces engine efficiency. An insoluble, abrasive slurry is created with fine particles creating friction by scraping and grinding against the piston rings and cylinder bore, rod bearings, valve train, gearing, piston pin, bushings, and other lubricated engine parts.

How Clean is Fresh Oil?

In general, oil in sealed smaller containers is cleaner than oil stored in the fleet's storage tank. The oil in some garage storage tanks can have up to twelve million particles per 100 milliliter at 4 microns (ISO 24). Other garages are filling their equipment from sealed container "fresh oil," which can have as little as one hundred thousand particles per 100 ML at 4 microns (ISO 17). In other words, the oil in the storage tank is *120 times* dirtier than the oil in the sealed containers. This is particularly disturbing when the oil reaches a level of ISO 21, approximately 1,500,000 particles per milliliter at 4 microns or higher. At this level of particle contamination many professionals believe that an oil change is required. If filled from a "dirty" storage tank with ISO 22 to ISO 24 oil, the "fresh oil" added to the engine would be two, four or up to ten times dirtier than the recommended oil change level.

How Is Oil Cleanliness Reported?

Laboratories measure particle contamination using several different methods. Once the number of particles at a given micron size is determined through laboratory analysis, the number of particles is converted to the ISO 4406 ratings from the International Organization for Standardization (ISO). ISO Codes provide easier comparisons of the cleanliness levels as set forth on the table below:

ISO 4406 Chart

Range Number	Number of Particles Per 100 Ml	
	More than	Up to and including
24	8,000,000	16,000,000
23	4,000,000	8,000,000
22	2,000,000	4,000,000
21	1,000,000	2,000,000
20	500,000	1,000,000
19	250,000	500,000
18	130,000	250,000
17	64,000	130,000
16	32,000	64,000
15	16,000	32,000
14	8,000	16,000
13	4,000	8,000
12	2,000	4,000
11	1,000	2,000
10	500	1,000
9	250	500
8	130	250
7	64	130
6	32	64

Why Is It More Difficult to Filter Finer Particles?

In short, because there are far more physical contaminates as the size of the particles decrease. The data below were taken from a garage storage tank of “fresh oil” unfiltered oil. The number of particles at 20 microns, there were less than 8,000 particles in the oil. At 6 microns, there were 368,500. At 4 microns, the number of particle contaminants increases dramatically to over 5 million, 5,593,200. Since there are more particles at the smaller sizes, it is especially important that the filter provide the highest level efficiency at the smallest sizes of 4 microns and below.

Microns	25	20	14	6	4
Particles	2,000	8,000	9,100	368,500	5,593,200

If a filter has an 80% efficiency at 4 microns is used to filter oil with 5,000,000 particle contaminates per 100 ML, the filter will capture 4,000,000 particles per 100 ML. A filter with 98% efficiency at 4 microns will capture 4,900,000 particles per 100 ML, removing 900,000 more contaminates per 100 ML from the oil than the 80% efficient filter. The additional 900,000 particles per 100 ML removed by the 98% efficient filter at 4 microns is more than twice the total number of all particle contaminants from 6 microns through 25 microns.

Can Microfilters Help Premium Oils?

Yes. As stated above, no oil can clean itself of physical contamination. When a synthetic oil or other premium oil becomes physically contaminated, the oil must be discarded to protect the engine even though these superior oils are still chemically viable (viscosity, TBN, etc.)

It has been said that “premium oils beg for better filtration” to achieve the full potential of the premium oil. Premium oils with more aggressive detergent qualities will clean up dirty engines, dissolving the sludge and other deposits, releasing more particles into the oil. Without microfiltration, the premium oil can produce unintended consequences. The high detergent qualities actually can make the oil dirtier as the built-up sludge and other deposits begin to dissolve and are suspended in the oil. *Physically* removing clearance level particles through microfiltration will capture the added contamination dislodged by the increased detergents. In time, the premium oil and the microfilter will reduce sludge and other deposits from a dirty engine.

Does the Lubrication Oil Break Down?

No. The base oil does not break down. Lubrication oil consists of approximately 80% base oil and 20% chemical additives. The chemicals additives are designed to be consumed during lubrication. Three factors limit the life span of lubrication oil: (1) particle contamination, (2) fuel or antifreeze contaminating the oil, or (3) chemical deterioration, such as high or low viscosity or high oxidation.

How Can Microfiltration Reduce EGR Engine Operating Costs?

In an Exhaust Gas Recirculation engine, (“EGR”), the EGR valve re-circulates exhaust gases into the intake stream. These gases displace some of the normal intake charge. This chemically slows and cools the combustion process by several hundred degrees, thus reducing NOx formation. Unfortunately, the EGR process also increases the amount of physical particulates in the lubricating oil, which results in higher lubricating costs. In some cases, the oil change interval is shorter. In other cases, the crankcase capacity is increased to hold more oil for the added particulates. In either case, lubrication service operating costs are increased. Microfiltration will keep the oil cleaner, thus improving the quality and useful life of the oil, which provides better engine protections and extended oil drain intervals.

Are Changes Required in Existing Maintenance Schedules?

No. The regular maintenance schedule is important. In addition to lubrication service, a number of other services and inspections are performed, which are required by relevant government regulations, manufacturer’s requirements and good maintenance practices. If a vehicle currently receives 12 monthly maintenance services, it still will receive its 12 maintenances services; however, the time required for the service is reduced. Microfiltration usually saves approximately 1 hour of oil bay time for a large vehicle. The two-thirds reduction would reduce the number of oil drain hours from 12 per year to 4 per year.

Are HEPO Filters® Easy to Service?

Yes. Unlike some microfilters, HEPO Filters® devices are easy to use. They are passive, non-mechanical devices, have no electrical or vacuum components, and are extremely rugged. They require only a few minutes to change the cartridge and to add approximately 0.75 quarts of make-up oil.

What Fleet Efficiencies Can Be Achieved?

For a fleet of 100 large vehicles (transit buses, cement mixers, freight haulers, etc.), HEPO Filters® can eliminate two-thirds of the oil services. On the first two oil intervals after an oil change only the high efficiency cartridge is changed and approximately 0.75 quarts of make up oil is added, a process which takes a few minutes. On the third oil interval, the oil is changed, the full-flow filters are changed, and the high efficiency cartridge is changed.

How Much Time do Fleets Save?

Here is an example for a 100 vehicle fleet, which currently has 12 oil changes per year, 1,200 oil changes. With microfiltration, the number of oil changes would be reduced from 1,200 to 400 a year. With the time saved from eliminating 800 oil changes per year, staff can be reassigned to higher skill tasks with more time to respond to other maintenance issues. A higher number of vehicles can be cycled through the oil bay areas. For a commercial boat fleet of 100, where the oil is changed weekly, the number of oil changes can be reduced from 5,200 a year to 1,733 a year. The amount of time saved would be greater because there would be 2/3rd less boat trips to the oil recycling facility. For a service van fleet of 100, usually the driver takes the van to an oil change facility, which takes *both* the vehicle and the driver out of services. Hence, the lost opportunity cost is greater than the oil change cost. In summary, the increased efficiencies with microfiltration and more eco-friendly maintenance, reduces waste, conserves oil, builds a sustainable nation, and saves money.

Microfiltration Basics

What is a Microfiltration?

Microfiltration is the process of crankcase oil recycling to remove abrasive "Clearance Level Particles" ("CLP") from the crankcase oil.

How Large are CLP Contaminates?

The size of CLP contaminants is generally from 2 to 25 microns.

Does the Full-Flow Filter Remove CLPs?

No. CLPs pass through the engine's full-flow filter. They are too small to be captured by the relatively porous full-flow filter media, which is designed for high flow-through, not slow depth filtration.

How do CLPs Cause Engine Wear?

CLP in the oil create an abrasive, insoluble, microgrit slurry, which causes friction, engine wear and premature oil changes. As CLP build up, engine wear increases even if the oil's other characteristics, such as viscosity and oxidation, remain viable.

Where is the Microfilter Installed?

The microfilter is installed in or near the engine compartment to supplement the filtration provided by the engine's full-flow filter. The microfilter is connected to the engine by an input hose and an output hose. The dirty oil flows continuously from the engine into the microfilter. After filtration, the clean oil flows back into the crankcase.

What is the Difference Between a "Bypass Filter" and a "Microfilter"?

The term "bypass" refers to *how* the device is attached to the engine. A filter can be in series ("in-line") or in parallel (by-pass) with the output stream from the oil pump. When a filter device is installed in the "bypass" mode, the stream is parallel with the main oil flow. Only a small portion of the oil is pumped into the bypass device, which then returns the oil to the crankcase, where it is re-circulated by the oil pump.

What is the Beta Ratio?

The "Beta Ratio," also referred to as the "Filtration Ratio," is a measure of the filter's capture efficiency at a specific micron size. The Beta Ratio is calculated by dividing the number of particles *before filtration* at a certain micron size (example, 10 microns) in the upstream oil stream, by the number of particles *after filtration* at that micron size in the downstream oil stream.

How does Filtration Efficiency Correlate with Beta Ratios?

The filter efficiency, called the Capture Efficiency Percentage (%), is determined by this formula (Beta -1/Beta) X 100. This produces the filter's efficiency, called the Capture Efficiency Percentage (%). For example, a Beta Ratio of 14 equals 93% efficiency, a Beta of 50 equals 98%.

What does "Absolute" Filtration Mean?

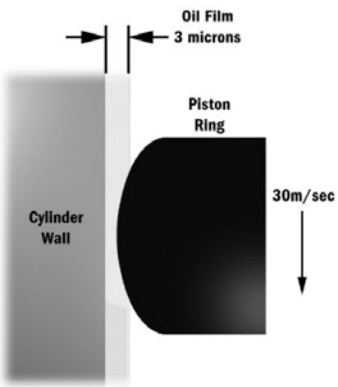
The Filter Manufacturers Council, *Technical Service Bulletin 89-5R3*, defines "Absolute" filtration as achieving an efficiency of 98.7% at the stated size, and "Nominal" filtration as achieving an efficiency of 50% at the stated size. HEPO Filters® provides cartridges capable of absolute filtration over the entire CLP 2 to 25 micron range.

What does "Filters down to 2 Microns" Indicate?

The phrase, "Filters down to 2 microns," by itself does not provide sufficient information to evaluate the filter's performance. The device could be only 8% efficient at 2 microns or 90% efficient at 2 microns. Filtration claims must include either a Beta Ratio or efficiency percentage; for example, 88%

efficient at 2 microns. One of the standard tests to determine the Beta Ratio and filtration efficiency percentage is the SAE J1858 Filter Element Multi-Pass Test.

How Do Microfilters Protect the Engine?



The microfilter protects the engine by removing the most harmful particle contaminants, the "Clearance Level Particles", "CLP". "As the engine operates it creates or ingests particle contamination, ranging from below .01 microns to over 70 microns. The Clearance Level Particles in the oil film are hard, insoluble, abrasive particles, which are small enough to enter into the clearance space between the moving parts but large enough to grind and scrape against the parts, such as the clearance between the cylinder wall and the rapidly moving piston ring, where the protective oil film is only 3 micron wide. A particle larger than the clearance can not enter into this 3 micron clearance area. A 0.1 micron particle can enter within the clearance between the cylinder wall and the piston ring but is not large enough to cause significant damage. The most damaging particles for a 3 micron clearance are 2 to 3 microns, which are both small enough to enter the clearance and large enough in the oil film to produce grinding and scraping damage. The majority of the engine clearances are in the 2 to 25 micron range.

What Are Clearance Level Particles?

There are numerous small clearances between the moving engine parts, such as the critical ring-to-cylinder clearance, which ranges from 3.0 to 7 microns. Hard particle contaminants that are small enough to fit inside the clearances but large enough to cause damage, will scrape and wear against the parts, especially if the particles are the same size as the oil film. Clearance Level Particles, "CLP," can range from as small as 0.5 microns up to 50 microns but generally fall within the range of 2 to 25 microns. The following table illustrates some of the clearances[5]:

Clearance Level Particles

Component	Oil Film Thickness (microns)
Ring-to-cylinder	3.0 – 7
Rob bearings	0.5 - 20
Main shaft bearings	0.8 – 50
Turbocharger bearings	0.5 – 20
Piston pin bushing	0.5 – 15
Valve train	0 – 1.0
Gearing	0 – 1.5

Does the Microfilter Replace the Engine's Full-Flow Filter?

No. The microfilter and the full-flow filter compliment each other in the same way as a good speaker system, where the higher notes are reproduced by the tweeter and the lower notes are reproduced by the woofer or subwoofer. The microfilter removes micro particle contaminants smaller than 35 microns down to 1 micron. The full-flow filter removes the larger particles larger than 35 microns.

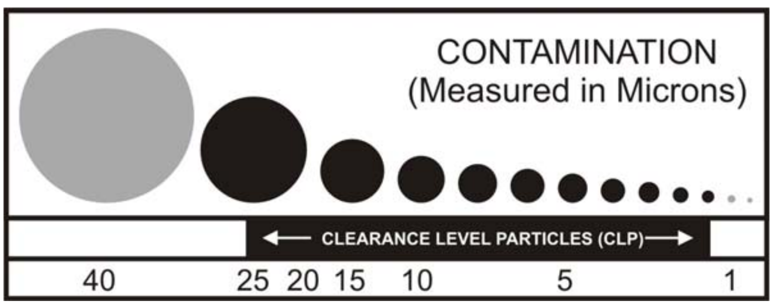
Why Can't Full-flow Filters Remove CLP?

The full-flow filter only can provide absolute filtration down to approximately 40 microns because it must use a more porous media to allow a large flow of oil to pass through without restriction. *All* the oil from the oil pump must pass through the full-flow filter before flowing to lubricate engine parts. If the full-

[5] Reprinted with permission, Fitch, James, C., Noria Corporation, *How to Select A Motor Oil and Filters for Your Car and Truck,* Figure 11, page 19; Illustration of diesel engine oil film thickness. (Permission for quotation does not imply endorsement of any product.)

flow filter slowly substantially and there were no safety valve, engine lubrication would cease, preventing lubrication and cooling of the moving parts, leading quickly to catastrophic engine failure. To prevent stopping the flow of oil to the engine, a safety valve is installed, which takes the full-flow out of the circuit if it become clogged. Inside the full-flow, the media offer a thin barrier designed to allow the rapid flow of oil through it. If dense media were used within the full-flow filter, it would quickly clog, preventing oil from flowing through it.

The design criteria for full-flow filters have not changed in fifty years, even though there have been many advances in other engine technologies. The criteria favor the rapid flow of oil over slow, depth filtration. A full-flow filter in a new CNG bus, for example is the same design found in a 40-year old full-flow filter in a 1967 GMC transit “fishbowl” or a Flxible “New Look” bus. In the older engines, full-flow filters came in canister-with-removable-cartridge designs and in one-piece, spin-on designs but the flow-through design characteristics were the same – the media is relatively thin to prevent premature cartridge clogging. As one can see from the figure below, there is a substantial difference between the large 40-micron ball on the left and the smallest one micron ball on the right. The full-flow media is designed to capture particulates down to approximately 35-40 microns, while the microfilter is designed to capture particulates down to approximately one micron.



What Is the Full-Flow’s Operating Environment?

The full-flow filter operates in-line under a high oil flow environment, typically 12 to 15 gallons per minute, (“GPM”) at 180 degrees or more with a 55 pound per square inch pressure (“PSI”). It provides absolute filtration down to approximately 40 microns. Because the device is “in-line” (in series), the design of the full-flow filter must assure that it does not starve the engine of lubricating oil. Even a moderate loss of oil flow could result in accelerated wear and major engine damage. A safety valve is installed in the engine or in the full-flow filter to take the full-flow “off-line,” that is out of the circuit, if it becomes clogged in order to assure that oil continues to flow to the engine parts. There is, of course, a trade-off: When the full-flow is off-line, it provides no filtration.

What is the Microfilter Operating Environment?

The microfilter operates with a very dense media and a low flow rate. The proprietary HEPO Filters® device operates typically between 0.1 to 0.2 GPM at 180 degrees with 55 PSI. It provides absolute filtration from 2 to 30 microns or more. The cartridge contains a patented “variable density design,” which provides both high efficiency and high particle retention, which removes the microgrit from the oil and captures it within the cartridge. The microfilter operates in a by-pass (in parallel) mode, using only a fraction of the oil stream, 0.1 to 0.2 GPM (versus 12-15 GPM for the full-flow). This is analogous to a small creek running parallel to a river.

One advantage of the by-pass mode is that if the microfilter cartridge were not changed and became clogged, the microfilter would not adversely affect the oil flow. In terms of the analogy, the river would continue flowing if there were no creek running next to it. The HEPO’s internal restriction nozzle allows it to operate continuously regardless of PSI. In contrast, at a high PSI, such as engine start-up or rapid acceleration, the full-flow filter safety valve may trigger, taking the full-flow off-line. HEPO Filters® devices continue to filter, regardless of engine pressure.

Microfilter Devices [6]

How Long Have Been Microfilters Been in the Market?

Although crude by today's standards, microfilters were in the market at least fifty years ago. The devices usually were called "bypass" filters because they were installed in parallel with the lubrication stream, rather than in series or in-line to the output from the lubrication pump. The term "bypass" covered several types of devices, including passive canister and active, mechanical devices. The early canister devices were not very efficient, often using paper towels or toilet paper in large, bulky canisters. The mechanical, centrifugal devices were temperamental. The early devices did provide supplemental filtration but had several drawbacks in terms of size, reliability, filtration efficiency, and contamination retention. True microfilters, capable of absolute filtration of clearance level particles, were not available until recent improvements in cartridge design.

What are the Various Types of Microfilters?

There are three basic microfilter designs: Centrifuges, canisters, and the so-called "oil refineries."

What is a Centrifuge Filter?

The centrifuge is a *mechanical* device, which rotates ("spins") at high speeds to produce a centrifuge action. The oil is sprayed onto a rotating outer bowl, where oil particles are pressed against the bowl. The bowl must be removed from the device for cleaning, which requires a cleaning solution, time and labor.

Centrifuges have three disadvantages: Filtering efficiency is not constant, installation is difficult, and centrifuges require more maintenance than other devices. Filtration efficiency is lower when vehicles operate in stop-and-go traffic, when the strain on the engine is higher and particle contamination is high. Filtration efficiency is higher when vehicles operate at relatively constant highway speeds, where engine strain is lower and particle contamination is lower. The lower cleaning power during idling and stop and go traffic is a problem for vehicles operated in city traffic, such as city transit buses, with frequent low-speed idling during passenger stops. It is especially problematic in hot weather on transit buses, due to the increased parasitic demands from the air conditioning compressor and generators to cool the bus and usually higher passenger loads. At this time when the engine is under its greatest strain, the centrifuge's cleaning power is at its lower efficiency. Second, centrifuges are more difficult to install than a canister device. The centrifuge must be installed vertically and most designs require a vacuum connection to the vehicle's air supply system for the centrifuge's control mechanism. Third, centrifuges are more maintenance intensive. A mechanic must remove and clean the centrifuge bowl in special solvents to remove the caked up particles and eventually, the centrifuge's moving parts also need to be serviced. This adds time, labor costs and creates a new form of contaminated waste in the cleaning solvent.

What is a Canister Filter?

Most canister filter designs consist of a disposable cartridge inside a canister. In a few designs, the canister/cartridge is in a one-piece disposable unit. Canisters are *passive, non-mechanical* devices, where particles are trapped in a disposable cartridge. Canisters are the most popular type of by-pass devices; however, they vary greatly in size, efficiency, and retention capacity. Canisters are easier to install and less expensive to maintain. Inside the metal canister housing, there is a removable filter cartridge. The early canisters were not very efficient. These early canisters often used paper towels for media, had limited cleaning power in the CLP range and media structural integrity problems. In addition, the early paper-towel canisters were very large, some retaining up to two gallons of oil. The major difference among the canister microfilters can be found in the design of the cartridge. HEPO Filters® uses 16-gauge steel exterior canister housing. Inside the canister there is a removable, patented, ultra-high efficiency cartridge.

[6] This copyrighted "Q & A on Microfiltration Devices" is used with permission from HEPO Filters, Inc.

What is an "Oil Refinery" Bypass Filter?

Some manufacturers add one or two components to their bypass filter and then label their devices as "oil refineries." Marketing a bypass device as an "oil refinery" overstates the device's abilities, as one can see by examining the process in an actual oil re-refinery facility.

How does an Actual Oil Refinery Facility Operate?

An oil re-refinery plant is a large processing facility. Re-refining oil is a sophisticated process involving chemical pre-treatment, dehydration, vacuum distillation, hydro treating, fractionation, and hydro finishing. This process creates the lubricating "base oil", which makes up approximately 80% of the lubricating oil. Next, the re-refined base oil must receive the other 20%, which consists of a mixture of chemical additives designed for the various oil specifications. These additives can not simply be poured into the base oil. Another process, called a blender operation, is required to produce the final product of re-refined lubrication oil.

What Add-On Features do Bypass "Oil Refineries" Provide?

These devices usually add a heating element and a chemical pack. The three components in the "oil refinery" are: (a) a canister portion with a filter element. This can provide adequate filtration, depending on the specific characteristics of the media used, which varies from one manufacturer to another, (b) an add-on heating device. A separate electrical connection is required to provide electrical power to the device, and (c) an add-on chemical pack, which adds chemicals to the oil as the oil circulates.

Why do "Oil Refineries" Heat the Oil?

The purpose of heating the oil is to flash off water vapor[7]. This feature provides limited value. The moisture in cold engine oil quickly evaporates when the engine reaches operating temperature, vaporizing the moisture, allowing it to be vented from the engine. After the engine warms up, lubricating oil even is briefly exposed to temperatures in excess of 300F degrees when it circulates around the combustion areas.

Can Adding Heat Harm the Lubricating Oil?

Yes. It is important to make sure that the oil refinery heating element shuts down and is not adding more heat when the engine reaches operating temperature of approximately 200F degrees. High lubrication oil temperature causes oxidation, which degrades the oil. When the engine temperature is raised by 10 degree C, the rate of oxidation approximately doubles. Due to the negative effects of high oil temperature, engine manufactures seek to *reduce oil temperature*, not to raise it. Most heavy-duty equipment and performance automobiles use oil coolers to *cool* the oil.

What Precautions are Needed Before Adding Chemicals to the Oil?

Oil sampling and testing are required to determine the characteristics and condition of engine oil *before* pouring any chemicals into the oil. There are many different types of lubrication oil, each with its own complex additive formulations. Adding the wrong chemicals may cause a serious negative reaction, such as creating non-conforming viscosity, chemical degradation and the destabilization of the lubrication oil. It is important to determine if the chemicals added by the various "oil refinery" devices are compatible with the fleet's engine oil.

What Type of Microfilter is Easiest to Install?

The compact canister-type designs, such as those offered by HEPO Filters®, Inc., are easiest to install. The large canisters are heavy, and do not fit within many engine compartment, such as in the popular diesel work trucks. Also, the large canisters often require a gallon or more of make-up oil each time the large, rolled paper towel-like cartridges are changed.

[7] HEPO Filters® offers a simple solution to controlling water vapor in a cold engine. The cartridge's dense cotton/cellulose media absorbs moisture from the cold oil. When the engine reaches its operating temperature of approximately 200F degree the water vapor begins to vaporize and is vented from the engine.

The centrifuges and the “oil-refinery” are more difficult to install than most canister designs. Both the oil refinery and the centrifuge must be installed vertically. In both designs, the oil flows back to the engine by gravity. This means that the centrifuges and oil refineries must be installed above the height of the engine’s oil return port. It sometimes is not possible to find a location in a cramped engine compartment. Canisters, on the other hand, have pressure oil returns and can be installed below the return port. The HEPO Filters® microfilter can be installed either vertically or horizontally, above or below the return port because the oil returns under pressure, not by the draw of gravity.

Bypass devices require an oil input and output port, however, many centrifuge designs, also require a vacuum pressure connection. Oil refineries require an electrical connection. Among the devices on the market, the HEPO Filters® compact canisters (various sizes depending on the size of the engine) are the easiest to install.

The Ideal Cartridge

What is the Ideal Cartridge?

The ideal cartridge must have three essential characteristics: (1) High Beta Ratios at the target micron sizes, such as the CLP range (2-25 microns), (2) High retention, the ability to hold a large amount of contaminants, and (3) High structural integrity to prevent media distortion, such as caking, surface build-up, or particles circumventing the filtering media, such as channeling and rupturing.

Is Filter Retention a Serious Problem?

Yes. Compare two filters, both with high Beta Ratios but one has low retention. The result is that the filter will operate with reduced efficiency under real-world conditions and will not deliver the specified efficiency over the full oil drain interval. The estimated retention capacity of HEPO Filters® cartridges is greater the 250 grams of contaminants.

What Factors Effect Structural Integrity?

The microfilter operates with oil flowing though it at a temperature of 180F degrees or higher, and an operating pressure of 55 PSI and higher when the engine accelerates. In addition, vehicles are subjected to bumps and jolts, which can jar the filtering media, causing channeling and rupturing. The patented HEPO Filters® cartridge design is far stronger than pressed cotton or rolled paper designs.

What is Filter Caking?

Filter caking is the build-up of contaminates around the surface of the media. One challenge in filter design is that a uniform low micron media will provide efficient cleaning but it also will clog more quickly due to caking around the circumference. If the media is a fine 4-micron media, then particulates will build up around the exterior surface, which will quickly choke off the flow of oil. This causes a short filter life. Using a 15-micron media will provide longer life but reduce cleaning of the smaller particles. In addition, under real-world conditions, cartridges prone to filter caking frequently have other structural weaknesses, which allow the particles to re-contaminate the oil. When a bus or a truck hits a pothole or other sudden jolting event, the cartridge is jolted. When jolted, often the contaminants caked around the circumference of the cartridge are dislodged. If the cartridge is also subject to channeling or rupturing, then the oil will be re-contaminated.

What is Channeling?

Channeling occurs when the oil entering the device creates a path through the cartridge back to the oil return, avoiding going through the filter media. When channeling occurs, filter capacity drops dramatically because most of the oil is not being filtered at all. It is simply starting at the surface, following a stream down to the return port on the device and returning to the engine unfiltered. Cartridge designs most prone to channeling are the compressed media designs.

What is Rupturing?

"Rupturing" is one of the most serious challenges. Rupturing occurs when the filter media collapses or the media tears. This can occur when the media design lacks structural strength, sufficient to withstand not only the 45-PSI usual operating pressure but also the high start-up pressure that can exceed 80 PSI. A ruptured media is broken open and does not provide filtration.

What are the Advantages of the HEPO Filters® "Variable Density" Design?

HEPO Filters® microfilters proprietary, patented cartridge provides high efficiency, high retention, and superior structural strength. The cartridge design avoids caking by using variable density filtration. The media at the surface is a larger size than the inner areas, which is designed to capture the finer particles. This allows the larger particles to be captured in the outer media of the cartridge, while allowing the finer particles to flow through the outer media into the denser inner media where the finer particles are captured. This "variable density" design avoids, filter caking, that is, clogging the filter on the surface.

The HEPO Filters® cartridge also prevents channeling with a patented blend of materials and overlapping, criss-cross winding pattern, which prevents the formation of open spaces that allow channeling. The oil cannot avoid passing through the media. The winding design also prevents rupturing by providing greater structural integrity to the media.

How often is the HEPO Cartridge Changed?

HEPO Filters® guarantees that the oil drain interval can be tripled. The vehicle's normal oil drain interval is defined as the interval when the vehicle's oil is changed. For some fleets, the normal oil interval is based upon the number of hours of engine operation, for example, 100 hours of engine operation. In other fleets the oil drain interval is based on mileage, for example, 6,000 miles.

At the vehicle first oil drain interval after an oil change (for example, 100 hours or 6,000 miles), only the HEPO cartridge is changed and a small amount of make-up oil is added. At the second interval, (for example, 200 hours of operation or 12,000 miles) only the HEPO cartridge is changed and a small amount of make-up oil is added. At the third interval, (for example, 300 hours or 18,000 miles), a full oil change is performed. Using this process will reduce the number of oil changes. If currently there are twelve oil changes per year, the number of oil changes will be reduces to four.

To assure oil quality, HEPO Filters® recommends regular oil sampling and analysis. Regular oil sampling assures a scientific, condition-based oil change program. Based upon oil analysis, the oil should be changed if anything abnormal is indicated, such as coolant contaminating the oil. On the other hand, if the oil remains viable, the oil drain interval could be further extended. Some garages now are equipped with oil analysis machines to provide quick feed-back.

What Type of Microfilter is Easiest to Maintain?

Canister-type designs are the easiest to maintain. HEPO Filters® products only require unscrewing the cartridge and installing a new cartridge. Like the full-flow filter, the used high efficiency cartridge can be crushed in the fleet's filter crusher, which squeezes out the used oil and creates a smaller form, then deposited in the recycling barrel, along with the crushed full-flow used oil filters.

Will Using a HEPO Filters® Microfilter Void My Warranty?

No. Using a HEPO Filters®, Inc. microfilter will not void the warranty. The company has received letters from most major engine manufacturers, which state that installing a HEPO Filter device does not void the warranty.

Will a HEPO Filters® Microfilter Work in Most Engines?

Yes. HEPO Filters® are offered various sizes, designed to fit virtually any engine, from a small automobile engine to a large commercial diesel. Our products are used in transit buses, cement mixers, construction equipment, police cars, commercial boats, small and large electrical generators, and ambulances. We have been manufacturing microfilters since 1992. We sell more microfilters in the USA than any other company does.