Dealer Training Series

Filtration Fundamentals

A Technical Introduction to Air and Fluid Filtration | Presented by AMSOIL INC.

Table of Contents

Filtration Fundamentals: Section 1
Introduction to Filtration

Introduction

This course has been designed as a technical introduction to the basic principles of air and fluid filtration and the various methods used to control contaminants within filtration systems. It is ideal for those who service or maintain mechanical equipment, and those who market AMSOIL products.

The material for this course is divided into three sections: the definition of a filter, common contaminants and their effects and types of media used in both air and fluid filtration. The second and third sections discuss air and fluid filtration respectively, and go into greater detail on each topic.

Section Objectives

After studying Section 1, you should understand and be able to explain the following terms and concepts:

1. The function of a filter
2. Effects of unchecked contaminants in air and fluid systems
3. Three main filter characteristics
4. Three main contaminants and how they affect lubrication systems
5. Range of contaminant sizes and the contaminant size of greatest concern
6. Flow vs. Efficiency Compromise and methods to minimize it
7. Seven filter medias and their applications (air, oil or both)

Section Keywords

The following keywords are defined in this section. Pay particular attention to their explanations as these concepts will serve as building blocks for future lessons.

Absolute Efficiency
Beta Ratio
Capacity
Cellulose Media
Efficiency
Filter
Flow
Foam Filtration Media
Full-Synthetic Media
Flow vs. Efficiency Compromise
Large Particles
Medium Particles
Micron
Nanofiber
Small Particles
Synthetic Nanofiber Media
Typical Full-Flow Filter Efficiency
Wetted-Gauze Media
Wire-Screen Filter Media

Filters & Why They are Important

A ***filter*** is a porous membrane that gas or liquid is passed through in order to separate out matter in suspension. In vehicular applications, this matter is dirt, dust, contaminants or particulates, all the same and all detrimental to air and fluid systems if left unchecked. Proper filtration results in two overall benefits: it ensures the equipment has a satisfactory service life and maintains the equipment's performance.

Filters are crucial in automotive applications because they remove contaminants that enter mechanical and lubrication systems. Without proper filtration, these contaminants would create significant damage to mechanical components. Contaminants, such as dirt and silicon particles, can be introduced from the environment or can be by-products of equipment operation. If left uncontrolled, these contaminants can cause accelerated wear on engine components and reduce equipment efficiency.

From a systems standpoint, filtration can be divided into two major types: air and fluid. Both are important and serve specific functions necessary to maintain vehicle cleanliness and efficiency.

Filtration Performance

A good filter is designed to perform well in a number of areas. When choosing an air or oil filter, three main filter characteristics should be considered.

The first of these is ***flow***. The filter must have the ability to flow an adequate amount of air or liquid for normal application operation.

The second consideration is the usable ***capacity*** of the filter. The filter must have adequate contaminant-holding capacity to remain in service for an acceptable period of time.

Finally, a filter's ***efficiency*** refers to its ability to adequately remove contaminants of a size critical for the application.

When considering filter performance, remember the ***flow vs. efficiency compromise***. A filter that is very open and free-flowing will generally have poor particle removal efficiency. Conversely, if a filter has excellent small-particle removal efficiency it will generally be more resistant to flow and have a relatively short life expectancy.

AMSOIL Ea Filters employ a number of mechanisms to mitigate the flow vs. efficiency compromise, including specialized design techniques and sophisticated materials and filter media. These specialized techniques and media types are discussed further in Sections 2 and 3.

Common Contaminants and Their Effects

Solid Matter (air & oil)

According to a study published by the Society of Automotive Engineers (SAE), approximately 400 tons of solid material is suspended in every cubic mile of air over a city. Even more solid matter is suspended over agricultural areas during certain times of the year. Of this solid matter, a significant portion is airborne dirt and dust. The dirt and dust found naturally within the environment is of greatest concern due to its abrasive nature.

Figure 1.1
Solid matter from the environment can reduce the life expectancy of an internal combustion engine by 60 to 80 percent.

Uncontrolled ingestion and circulation of air-bound abrasive material can reduce the life expectancy of an internal combustion engine by as much as 60 to 80 percent, which is why filtration is so crucial to engine and component life. The minute particles found naturally in the environment can significantly increase wear to engine components, ultimately limiting the engine's operating life.

In four-cycle engines, dirt and dust contamination can result in valve-guide wear. Dirt and dust that reaches the combustion chamber can increase piston and ring wear and damage the cylinder liner. These particles are eventually carried by the oil to other engine components such as bearings, crankshafts and camshafts.

Major Causes of Premature Bearing Failure	
Dirt	49%
Assembly	13.4%
Misalignment	12.7%
Insufficient lubrication	10.8%
Overloading	9.5%
Corrosion	4.2%
Other	4.5%

Figure 1.2
Almost half of all bearing failures can be attributed to dirt.

Water (air & oil)

Water accounts for up to 4 percent of the air. When conditions are right, that water condenses into liquid form and enters lubrication systems. The effects can be catastrophic. Water reduces oil's ability to lubricate and can combine with other molecules to cause chemical reactions that form corrosive compounds and acids. Most recognizably, water promotes the formation of rust, increasing the potential for harmful rust contamination to develop within the system.

Soot (air & oil)

Soot is a fine, dark powder that results from incomplete combustion. Modern engines are designed to capture soot in the oil; while electronic controls and high injection pressures have significantly reduced the levels of soot produced during combustion, it remains an impurity that must be managed within the lubrication system.

As soot levels increase within the crankcase, the effectiveness of the lubricant's dispersant additive is reduced, causing the soot to cluster into larger particles that increase wear to critical components.

Contaminant Size

Contaminants suspended in air or fluid can be very small. To grasp just how small these particles are, an understanding of the measurements involved in their classification is necessary.

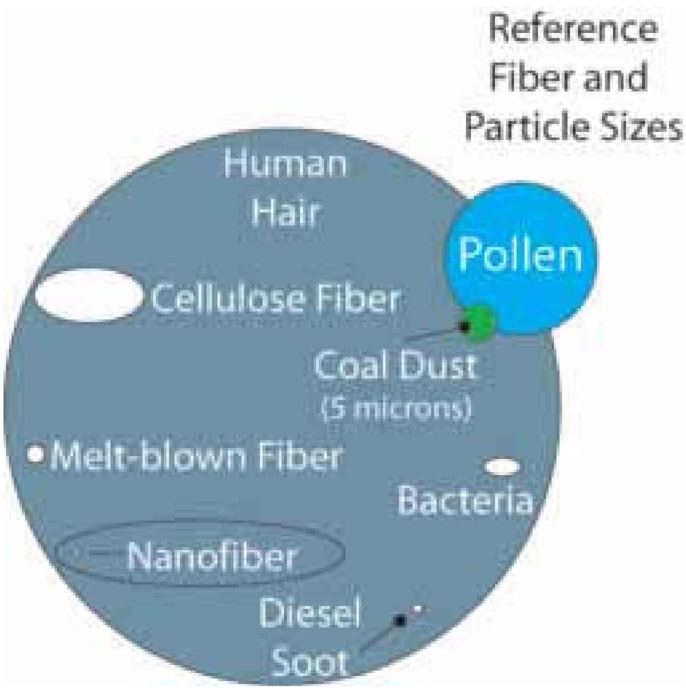


Figure 1.3
The size of nanofibers is equal to one millionth of a meter - smaller than the diameter of a human hair.

A ***micron*** (μ), or micrometer, is a very small unit of linear measurement equal to one millionth of a meter, or .00000039 inches. To get an idea of the sizes that micron measurements relate to, consider the following examples:

- The diameter of a human hair is 50 to 100 μ
- The smallest particle visible without magnification is 40 μ

Large particles, which measure 0.5" or larger, pose only a small threat to lubrication systems because they are easily filtered out from the intake air stream.

Medium particles, which measure 25 μ to 0.5," are more difficult to filter from the air stream and are of greater concern. However, the threat of medium particles is diminished because they are larger than many of the clearances within an engine. Their size prevents them from entering the contact areas between many components and limits their ability to cause accelerated wear.

Small particles, those in the 5 - 25 µ range, are the cause for greatest concern because their size allows them penetrate the clearances between wear-sensitive components. Once these small particles become lodged in the gaps between components, contact occurs and results in increased friction and wear. The size of these particles makes them particularly difficult to remove from the lubricating system.

Particles smaller than 5 µ, in general, can be suspended safely within the oil film and pose little threat.

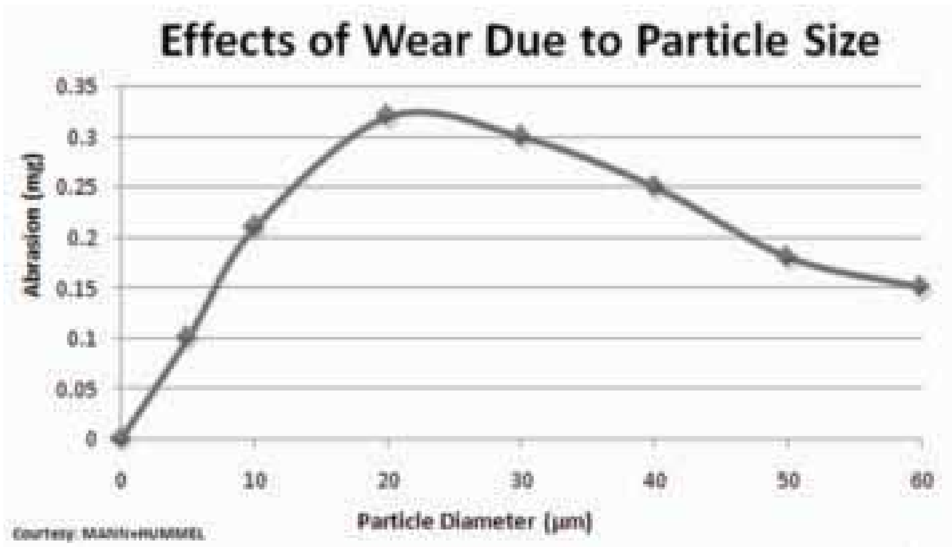


Figure 1.4
Particle size effects on wear. (Courtesy of MANN+HUMMEL)

Flow vs. Efficiency Compromise

The ***flow vs. efficiency compromise*** refers to the converse relationship of flow and efficiency and how it effects filter media density. As the density of filter media increases to improve efficiency, the ability of air or fluid to flow through the media is diminished.

The flow vs. efficiency compromise presents a challenge for filter engineers. Filter efficiency can be improved by increasing media density; however, media that is too dense restricts flow and does not provide adequate amounts of air or liquid for optimum performance.

One common method of mitigating the effects of the flow vs. efficiency compromise is increasing the filtration surface area by folding or pleating the media.

Filter Media Types

This section covers the various types of filter media; some of which are used in both air and oil applications, while others are best-suited to one application or the other.

Common types of air filtration media include cellulose, wetted-gauze, nanofiber, open-celled foam and synthetic fibers.

Common types of oil filtration media include cellulose, cellulose/synthetic blend, wire screen and full synthetic.

Cellulose Media (air & fluid)

Cellulose media is a natural media derived from plant fibers. The fibers are rough in texture and vary in size and shape. Cellulose fibers are typically heat-cured and mixed with resins to increase stiffness. Cellulose media has been used for many years and is employed in the majority of filters in the market. Its performance varies depending on processing and the type and amount of resin used to bind the fibers. Filters produced with cellulose media are usually designed to meet original equipment manufacturer's (OEM) requirements and provide adequate performance.

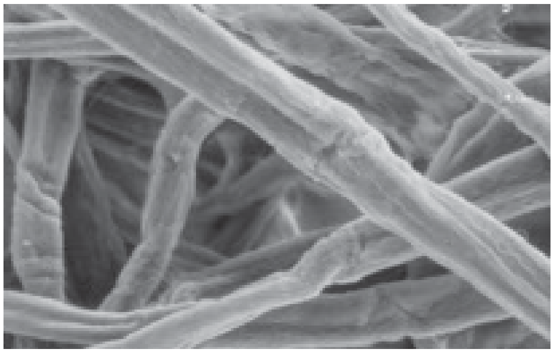


Figure 1.5
Cellulose fibers made from plant materials

Cellulose/Synthetic Blend Media (fluid)

Cellulose/synthetic blend media typically consists of cellulose fibers combined with high amounts of bonding resins and various amounts of glass or polymeric fibers. Cellulose/synthetic media filters normally provide better efficiency and capacity than cellulose media filters.

Wetted-Gauze Media (air)

Wetted-gauze media is a naturally occurring material often used in air filters. Wetted-gauze filters are composed of layered cotton fibers wetted with a tacking oil to trap contaminants. This media is usually employed in high-performance filters where high airflow is required; however, filtering efficiency is generally compromised. Wetted-gauze filters require repeated cycles of washing and re-oiling, which can reduce their effectiveness.

Synthetic Nanofiber Media (air)

Polymeric refers to a chemical process that creates a structure of repeating molecular elements. ***Nanofiber*** is a term used to describe fibers with a diameter less than 1 μ. The consistent structure and small size of polymeric nanofibers enable high efficiencies. Recently, ***synthetic nanofiber media*** has been used in conjunction with cellulose media to create a composite, high-efficiency filter. The combination features cellulose media covered by a thin layer of polymeric nanofibers to increase efficiency with minimal impact to airflow. Filters produced with synthetic nanofibers on cellulose 'composite' media can be cleaned using compressed air or a vacuum.

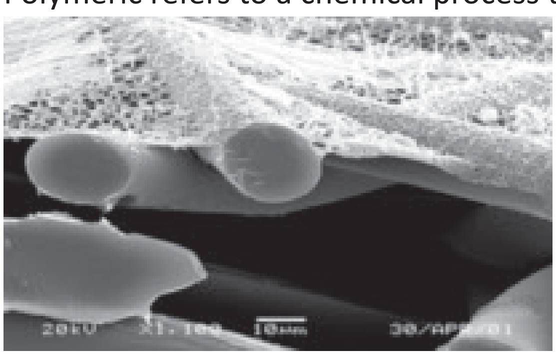


Figure 1.6
Synthetic nanofibers on cellulose media

Foam Filter Media (air)

Foam filter media has been available for many years, mainly for use in smaller engines; however, it has also been successfully used in automobile, powersports and large-truck applications. ***Foam filtration media*** is generally reticulated (open cell) foam made of polyester or polyether/polyurethane material. Pore size is controlled and ranges from 10 pores per inch (PPI) to 80 PPI depending on intended application.

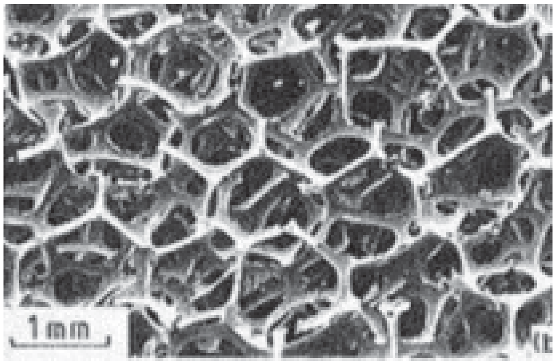


Figure 1.7
Open-celled foam media

Foam media is heat resistant to 455°F (235°C), and with void space making up 97 percent of the media, airflow is increased. As with wetted-gauze filters, tack oil applied to the foam helps capture and retain contaminant particles. Foam filters are advantageous in high-dust conditions because they can be cleaned and reused.

Full-Synthetic Media (air & fluid)

Full-synthetic media is synthesized from polymeric nanofiber materials such as non-woven polyester fibers and melt-blown glass fibers. It has high loft, or fluff, which improves media thickness and increases contaminant-holding capacity. Synthetic fibers of differing sizes, density and layers can be engineered with specific airflow rates and efficiencies. Many foreign automobile manufacturers specify full-synthetic air filters, and the vast majority of cabin air filters are constructed with this media type.

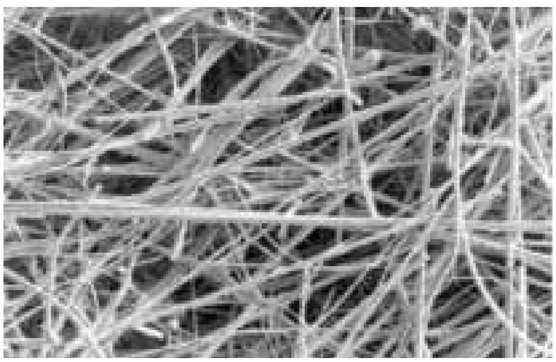


Figure 1.8
Full-synthetic media

In fluid applications, synthetic fibers of various sizes and densities can be engineered to control efficiency and oil flow rates. Synthetic media works well in oil applications because it is more resistant to hot oil over a longer period of time as compared to cellulose and cellulose-blend filters.

Wire-Screen Media (fluid)

Wire-screen filter media technology has been used for many years in fluid applications. It is composed of wire strands that are woven together to form a resilient, heat-resistant filter that can withstand routine cleaning. Wire screen media can be constructed of aluminum, stainless steel, carbon steel, brass or copper. Wire filters that depend on the sieving filtration mechanism provide capacities less than those of cellulose, cellulose-blend and synthetic filter media, and are mainly found in industrial or racing applications.

Section 1 Review Questions

1. The major cause of premature bearing failure in automotive engines today is __________.

2. Without air filtration, an engine's life can be reduced by as much as _____-_____ percent.

3. 3. List two reasons why filtration is important.
   ____

   ____

4. What is the inherent challenge of designing a filter? Name one way this effect can be minimized.
   ____

   ____

5. Contaminants in the ______ to ______ micron range cause the greatest amount of wear on an engine.

6. ___________ is a common filter media, derived from plant material.

7. Which filter media offers high efficiency and can be cleaned using compressed air or vacuum?
   ____

   ____

8. What filter media type can be engineered to target specific flow rates?
   ____

   ____

9. The purpose of the pleats in filters is to increase surface area.

   True or False

Filtration Fundamentals: Section 2
Air Filtration

Introduction

This section of Filtration Fundamentals covers the basic principles of air filtration. A thorough understanding of basic principles of air filtration is essential for providing exceptional customer service.

Section Objectives

After studying Section 2, you should understand and be able to explain the following terms and concepts:

1. The air filter's role in an engine
2. The Stoichiometric ratio and variances in its real-world application
3. The four air filtration mechanisms
4. Benefits of Depth Screening vs. Surface Screening
5. Benefits of using nanofibers in air filters
6. Benefits of AMSOIL Ea Filters

Section Keywords

The following keywords are defined in this section. Pay particular attention to their explanations as these concepts will serve as building blocks for future lessons.

Adsorption Filtration
Cubic Feet of Air Flow per Minute (CFM)
Depth Screening
Diffusion
Filter Minder
Manometer
Nanofibers
Oil-Wetted Foam
Stoichiometric Ratio
Surface Screening

The Importance of Air Filters

Section 1 of Filtration Fundamentals explained what a filter does, how it functions and why it's important. Ninety percent of the contaminants within an engine come from the air, and the air filtration system serves to eliminate, as much as possible, these contaminants in order to reduce engine wear.

Air is a necessary component of the combustion process, and the air filter is the engine's first and most important defense against dirt and other harmful contaminants that are suspended in air. As noted in Section 1, abrasive contaminants entering an internal combustion engine can reduce the engine's life by 60 - 80 percent if left uncontrolled.

Stoichiometric Ratio

Three elements are needed to create energy in an internal combustion engine: oxygen, fuel and a heat catalyst. The heat can be produced by an electronic spark (gasoline engine) or generated during compression of a fuel and oxygen mixture (diesel engine).

The ***stoichiometric ratio*** is the ratio of oxygen to fuel that, theoretically, produces the greatest release of energy. In automotive applications the stoichiometric ratio is 14:1 (oxygen/fuel by weight); however, in real-world applications this ratio frequently varies anywhere between 14:0.85 to 14:1.25, depending on engine type (gasoline or diesel) and operating conditions.

Air Filter Media

Common air filter media, including cellulose, wetted-gauze, nanofiber, foam and full synthetic, were discussed in Section 1 of Filtration Fundamentals. Refer to that section for full descriptions of these media types.

Air Filtration Mechanisms

There are four basic methods used to control air-suspended contaminants; each has advantages and disadvantages. Although most filters are based on a single filtration method, some use a combination to improve overall performance.

Surface Screening

Surface screening is the simplest of the four filtration methods and consists of a two-dimensional matrix of open areas and solid dividers. An example of a surface screen filter is the common window screen that keeps pests and large debris from entering a home.

Surface screening, also known as mechanical separation, removes contaminants from the air stream if they are larger than the opening in the screen matrix. Contaminants smaller than the screen openings will pass through. The smaller the opening, the smaller the particle that will be retained; however, smaller openings also restrict airflow to a greater degree.

Surface screening filters are generally constructed of metal or plastic. They tend to be inexpensive and can be easily serviced and reused. Their limited surface area results in low contaminant-holding capacity. Because they must contend with the flow vs. efficiency compromise, their small-particle removal efficiencies are generally lower than those of other filtration methods.

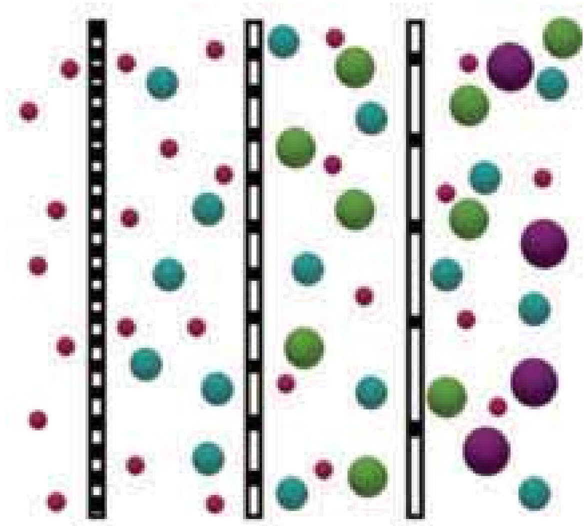


Figure 2.1
Surface screening. The smaller the opening, the smaller the particle that will be retained.

Depth Screening

Instead of the two-dimensional matrix used in surface screening, ***depth screening*** adds a third dimension of thickness. By arranging media fibers on top of each other, a variety of opening sizes are created throughout the media. Conventional surface screening occurs on the outside of the media with additional contaminant removal occurring as air passes through the media depth. This added layer results in greater contaminant capacity than what is possible with surface screening alone.

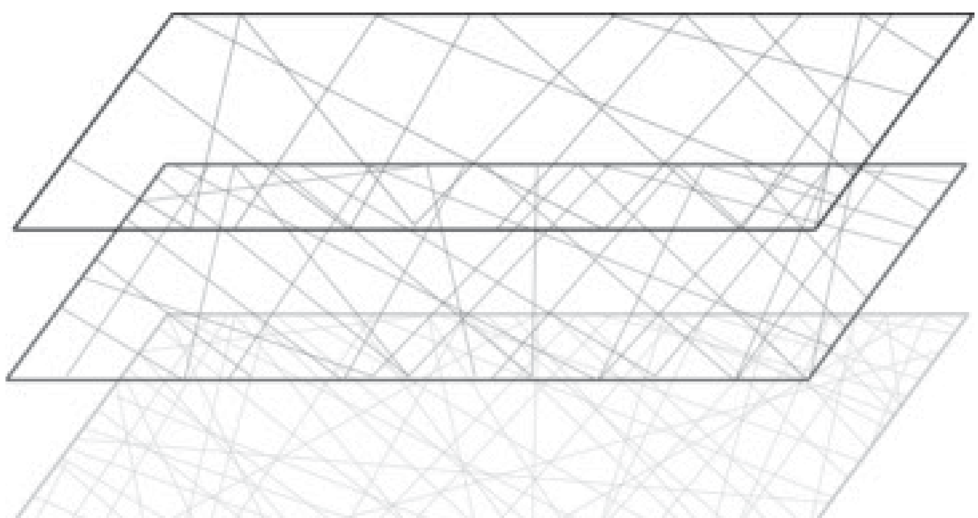


Figure 2.2
Depth screening. Depth screening adds a third dimension of thickness that creates various size openings and improves contaminant capacity.

The third dimension also improves small-particle removal efficiency and reduces the flow vs. efficiency compromise, providing more airflow

through the filter media while removing more particulate matter.
The paper air and oil filters commonly used in modern automobiles are examples of filters that employ depth screening. The media used in such filters consists of a blend of cellulose material to which resins have been added to increase structural strength and minimize deterioration from water. Glass fibers may also be added to increase structural strength and aid in pore-size uniformity. These glass fibers are rarely used as the sole component of air filters, but are common in the construction of high-end hydraulic filters.

Adsorption

Adsorption filtration does not use a mechanical filtration method like those used in screening filtration. Instead, particles are removed from the air stream through attraction to a negatively charged surface, or by contacting a surface composed of a sticky or tacky material. This type of filtration is uncommon in the transportation industry.

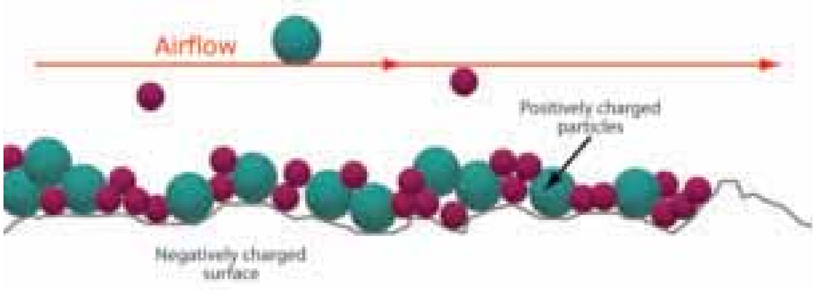


Figure 2.3
Adsorption. Particles are retained via the sticky or tacky properties of the surface.

Diffusion

In the filtration principle of ***diffusion***, airborne particles are separated from a diverted air stream according to their weight. As air moves, any suspended contaminants are accelerated within the air stream. Due to their greater weight, contaminants tend to move more or less in a straight line and will not change direction as easily as the air molecules around them.

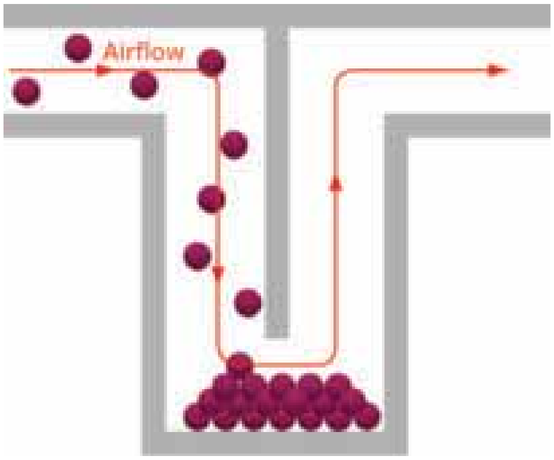


Figure 2.4
Diffusion. Contaminants separate out when air changes direction.

In an old automotive oil-bath filtration system, air is drawn down a channel and forced to make a 180° directional change. The weight of the contaminants causes them to separate from the air when it changes direction. Once the contaminants have been separated, they are retained on a surface covered in tack oil.

Airflow and Filter Performance

Adequate airflow is essential for an engine's performance. A filter's ability to flow air is usually reported in ***cubic feet of airflow per minute (CFM)***. Resistance is a measure of a filter's ability to pass a volume of air through the filter media. The degree of resistance is determined by measuring the difference in pressure (pressure differential) between the outside of the filter and the pressure inside the filter at a given flow rate. The greater the resistance to airflow for a given volume of air, the greater the pressure differential across the filter media.

A ***manometer*** is a device used to indicate a pressure differential within a system. The greater the resistance to flow, the higher the fluid will rise in the manometer. The degree of resistance is reported in inches of water or mercury, depending on the construction of the manometer. (See figure 2.11 on page 23)

One filter's flow performance can only be compared to another's when the rate of flow has been determined at identical levels of restriction and the same units of restriction (water or mercury) are used.

The ***filter minder*** indicates when the pressure differential between the outside and inside of the filter element becomes too high and the filter is too clogged for air to pass through to the engine. Original equipment manufacturers (OEMs) determine the proper pressure differential for each application.

Nanofiber Technology

Nanofiber air filter technology, patented by Donaldson Company, is employed on the US Army Abrams M1A1 tanks in desert conditions. These filters, equipped with reverse pulse technology, are designed to minimize soldier maintenance and possible exposure to the enemy.

At less than one micron in diameter, ***nanofibers*** are considerably smaller than traditional cellulose and synthetic filter media. Nanofibers trap sub-micron contaminants on the media's surface layer.

The polymeric nanofibers used in filter media are made using an electro-spinning process where an electrical field is used to draw a polymer solution from the tip of a capillary to a collector device. The fine jets dry to form polymeric fibers that can be collected on a web (sometimes called a nanoweb).

Nanofibers on Cellulose Media

The average diameter of a strand of cellulose fiber is approximately 15 µ, melt-blown material is about 2 µ and nanofibers are less than 1 µ. Recall that a human hair ranges from 50 µ to 100 µ, so the scale of nanofibers is infinitely small and cannot be seen with the naked eye.

The following illustration demonstrates how the combination of nanofibers and cellulose media works to maximize efficiency. Imagine two filtration media, a chain-link fence (cellulose fiber media) and a mosquito net (melt-

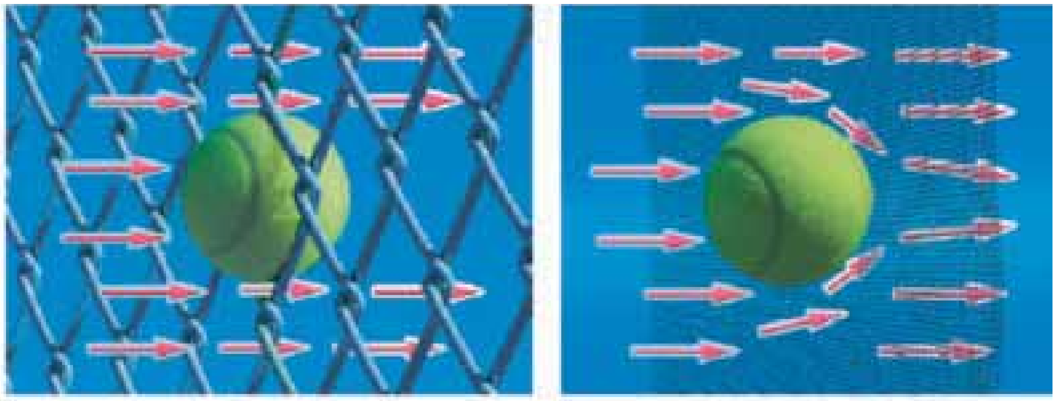


Figure 2.5
The tennis ball obstructs airflow of the larger fibers and larger holes, while it obstructs much less air against media composed of smaller fibers and smaller holes.

blown & nanofiber media). Each is required to stop contaminants, in this case a tennis ball.

The tennis ball will fit into the opening of the chain-link fence very well and obstructs almost 100 percent of the air from flowing through it. Now, imagine a tennis ball against a mosquito net. The tennis ball, at the point of contact with the netting, will obstruct much less filter area than the chain-link fence example. Air is still able to flow around the tennis ball all the way to the point of contact. It will take many more particles to obstruct the netting surface area than it would to obstruct the chain-link fence.

Cellulose fibers are larger than nanofibers and have larger spaces between the fibers, causing contaminants to be held in the depth of the media and plugging the airflow path. This results in higher restriction and less capacity, meaning that cellulose is a less efficient filter media than nanofiber media.

When synthetic nanofibers are laid on top of a cellulose base to create a dual-layer media, it creates smaller inter-fiber spaces that result in higher

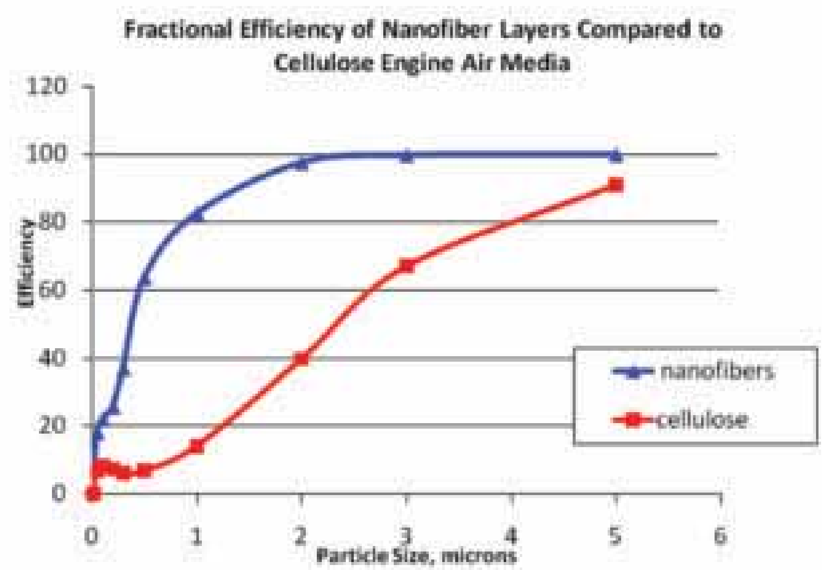


Figure 2.6
The smaller spaces created by nanofiber media increases contaminant capturing efficiency.

efficiency. By trapping submicron contaminants on the surface, rather than dispersing them throughout the depth of the filter, nanofibers are able to stop particle contaminants while maintaining an airflow path.

These qualities are crucial in on-highway applications because the contaminants in highway environments are primarily sub-micron size.

AMSOIL Ea Air Filters

AMSOIL Ea Air Filters

AMSOIL Ea Air Filters (EAA) are made with a nanofiber coating on the surface of a specially formulated cellulose media.

Figure 2.7
AMSOIL Ea Air Filters

This custom media is designed to flow more air and provide superior efficiency over filters made using cellulose, synthetic or foam media. In addition, Ea Air Filters can be cleaned with vacuum or shop air, providing increased filter life compared with traditional air filters.

Ea Air Filter Life

AMSOIL guarantees Ea Air Filters for four years or 100,000 miles, whichever comes first, as long as the filter has been cleaned according to AMSOIL cleaning instructions. The warranty does not include operation in off-road, competition or extremely dusty environments. In these conditions the filter should be cleaned more often or per restriction gauge, if so equipped.

AMSOIL Advantage

AMSOIL Ea Air Filters use a proprietary combination of special-grade cellulose media and nanofiber media for enhanced efficiency and flow. AMSOIL Ea Air Filters have higher efficiency, greater capacity for fine dusts and longer filter life compared to traditional cellulose, foam and gauze filter media. Dust remains on the surface of Ea Air filters and can be cleaned to provide a longer-than-average service life. AMSOIL Ea Air Filters offer better engine protection with increased flow and capacity for longer service life and reduced maintenance costs.

AMSOIL Ea Universal Air Induction Filters

Aftermarket air-intake systems, typically referred to as air induction

Figure 2.8
AMSOIL Ea Universal Filters

systems, are used to replace the OEM air filter and inlet hose in order to provide increased airflow to the engine. The purpose of increasing the airflow to the engine is to increase horsepower created during combustion.

AMSOIL Ea Universal Air Induction Filters (EAAU) replace stock oil-wetted gauze and foam conical filters supplied with induction systems. AMSOIL Ea Universal Air Induction Filters are cleanable for longer life and provide better efficiency and excellent airflow.

AMSOIL Ea Universal Air Induction Filters feature the same nanofiber media found in AMSOIL Ea Filters for car and light-truck applications. The media is pleated with epoxy-coated wire on the face and back side for additional strength and stiffness. High-quality, pliable urethane connectors with plastisol potting complete the product. Each filter comes with a clamp for convenient installation.

Figure 2.9
AMSOIL Ea Racing Filter

AMSOIL Ea Racing Air Filters

AMSOIL Ea Racing Air Filters (EAAR) provide Ea protection for carbureted applications. AMSOIL Ea Racing Air Filters provide additional filtering area by allowing air to flow through the top lid, which is made of nanofiber media. The filter is also exposed, allowing air to flow through the side and adding even greater air intake capability and efficiency. AMSOIL Ea Racing Air Filters are cleanable and reusable. They are 14” in diameter, and the top of the filter features aluminum trim rings with the AMSOIL logo etched into the top edge.

Figure 2.10
AMSOIL Ea Motorcycle Air Filter

AMSOIL Ea Motorcycle Air Filters

AMSOIL Ea Motorcycle Air Filters (EAAM) replace OEM filters from Harley-Davidson and Honda, as well as filter housings from S&S and Baron. AMSOIL Ea Motorcycle Filters provide better efficiency, excellent airflow and are cleanable for long filter life. AMSOIL Ea Motorcycle Air Filters are also made with nanofiber media and are constructed from the highest-quality materials.

AMSOIL Advantage

Employing advanced media types and exceptional construction, AMSOIL Ea Air Filters offer many advantages to motorists. AMSOIL Ea Air Filters provide superior efficiency, greater contaminant-holding capacity, enhanced flow and are cleanable for reuse. These benefits translate to superior performance and protection while remaining cost effective.

- Nanofibers on cellulose media for enhanced flow
- Higher efficiency, ensuring better engine protection and longer equipment life
- Greater airflow for maximized equipment performance and energy conservation
- Greater contaminant capacity, extending service intervals
- Cleanable, extending service life beyond the average filter

Signs of Air Filtration Problems

There are many signals that can suggest an air filtration problem. An oil analysis report indicating elevated component wear or an unusual increase in oil consumption could be traced to ingestion of abrasive material. Significant changes in equipment performance or fuel consumption are also indicators of air starvation problems and could suggest the existence of a filtration deficiency.

Be alert and take note of any signs of dirt on the clean side of the air intake. If dirt is noticeable, there is certainly dirt inside the equipment.

Industry-Accepted Standards for the Evaluation of Air Filters

Air filters are tested in accordance with the Society of Automotive Engineers (SAE-J726) or International Organization for Standardization (ISO-5011). Both methods use A2 fine or coarse test dust as the contaminant. The test dust is injected into the air current passing through the system, collected on the test filter and finally onto the absolute filter. Filter masses are determined before and after contaminant injection. The efficiency of the filter can be calculated by comparing the amount of dust injected and the amount captured by the test filter and absolute filter.

The test dust has a particular particle-size distribution and all filters should be tested according to this standard. An absolute micron rating of an air filter is misleading. Filter efficiencies need to be compared using the same test method and test dust. Special testing is required if a manufacturer claims a certain efficiency at a specific micron level.

Capacity is determined by adding contaminants to the filter with a specific volume of air passing through the system until the restriction reaches an OEM-specified level.

Filter openings become restricted as contaminants are held by the filter media. As shown in Figure 2.11, a manometer device attached to the inlet and outlet sides of the filter indicates the amount of filter restriction based on the amount of displaced water or mercury in the manometer. For auto and light-truck applications, this restriction is normally 10” of water.

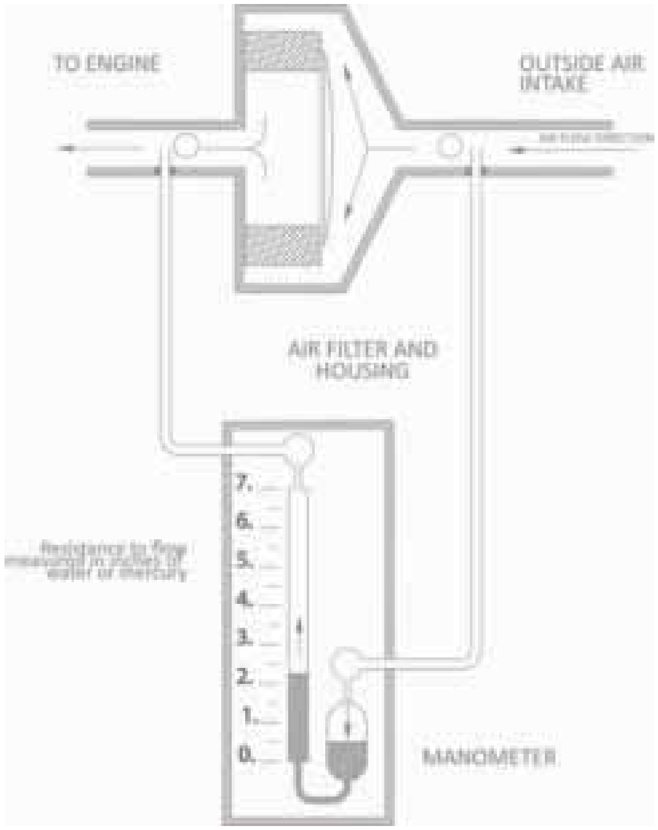


Figure 2.11
Manometer device used to measure a filter’s restriction

Section 2

Section 2 Review Questions

1. The air filter is an engine's best defense against dirt.

   True or False

2. What percentage of contaminants within an engine comes from the air?

3. Theoretically, the ratio at which fuel and oxygen are mixed to result in the greatest release in energy is known as the ______________________ ____.

4. List the 5 types of air filter media

   ____

   ____

   ____

   ____

   ____

5. List the four filter mechanisms

   ____

   ____

   ____

   ____

6. The simplest air filtration mechanism is ____________________________

   ____.

7. How does Depth Screening differ from Surface Screening, and what are the benefits?

   ____

   ____

8. ____________________ are often added in Depth Screening to increase structural strength and pore-size uniformity.

9. The ____________________ air filtration mechanism relies on the weights of the airborne particles to separate them from a diverted air stream.

10. The __________________________________is a device that will alert when the pressure between the outside and inside of the filter becomes too high, indicating the filter is too clogged for air to pass through.

11. What two methods may be used for cleaning AMSOIL Ea Air Filters?
____

____

12. What is the AMSOIL Ea Air Filter guarantee?
____

____

13. What are some symptoms of an engine not getting adequate air flow?
____

____

Filtration Fundamentals: Section 3
Oil Filtration

Introduction

This section of Filtration Fundamentals examines oil filtration. Oil filtration is a broad term covering a variety of applications and fluids, including hydraulic oils, engine oils and gear oils. There are many similarities and differences in how filtration is addressed in these different applications and fluids.

Section Objectives

After studying Section 3, you should understand and be able to explain the following terms and concepts:

1. The oil filter's role in the engine
2. The two main sources of engine oil contaminants
3. The three basic components of an oil circulation system
4. The four particle-capture mechanisms
5. Differences between full-flow filtration systems and by-pass filtration systems
6. Advantages of combining full-flow and by-pass filtration systems
7. The seven components of the spin-on filter cartridge
8. How AMSOIL Ea By-Pass Filters differ from typical by-pass filters

Section Keywords

Anti-Drainback Valve
Base Plate
Base Plate Gasket
Brownian Movement
By-Pass Valve
Diffusion Mechanism
Filter Housing
Follower Plate
Hold-Down Spring
Hold-Down Strap
Inertial Impaction Mechanism
Interception Mechanism
Oil Reservoir
Plumbing
Pressure Differential
Pump
Relief Valve
Sieving Mechanism
System Pressure
Tension Spring

The Importance of Oil Filters

Oil is the lifeblood of an engine. Motor oil must help prevent wear, maintain cleanliness, reduce operating temperatures and act as a seal. When contaminants enter the oil, its ability to perform these functions is diminished.

It's not possible to completely eliminate contaminants that are present in the engine; however, they can be adequately controlled with proper filtration. Engine oils become contaminated from external and internal sources through normal use.

External contamination sources include dirt, dust and water that enter the engine through the air-intake system, breather system or unwanted openings in the equipment. External contaminants such as dirt and dust are abrasive, and their presence in the oil will result in accelerated wear.

Internal contamination sources include particles generated from wear and combustion by-products that blow past the piston rings. These particles all have a negative effect on the oil, including sludge formation, harmful acid development and excessive wear.

Solid contaminants in the oil supply are addressed with conventional filtration, but water, fuel and acids are typically handled by the oil's additive chemistry because filtration generally offers little assistance in those areas. However, there are specialized filters, such as AMSOIL Ea By-Pass Filters, that can aid in several of these areas. AMSOIL Ea By-Pass Filters and the benefits they provide are discussed later in this section.

Superior Filtration: Worth the Price?

Many motorists question whether superior filtration is worth the additional price. It is important to consider that 60 to 80 percent of component wear is directly contributed to the presence of abrasive particles within the lubricant. Filtration can eliminate or significantly reduce the concentration of these materials. The end result is reduced wear, longer equipment life, less downtime and lower cost of operation.

According to a General Motors study, the use of superior filtration has the potential of increasing engine life by as much as eight times over traditional filtration mechanisms. Information released by Needleman and Zaretsky (1991) indicates that in roller bearings alone, moving from a 40 µ filter to a 10 µ filter will double the life of the bearing. For ball bearings, this change in filtration can increase the life of the equipment by 42 percent.

Something as simple and cost-effective as proper oil filtration can ensure long engine life, excellent component protection and significant amounts of money saved over time.

The Dangers of Soot

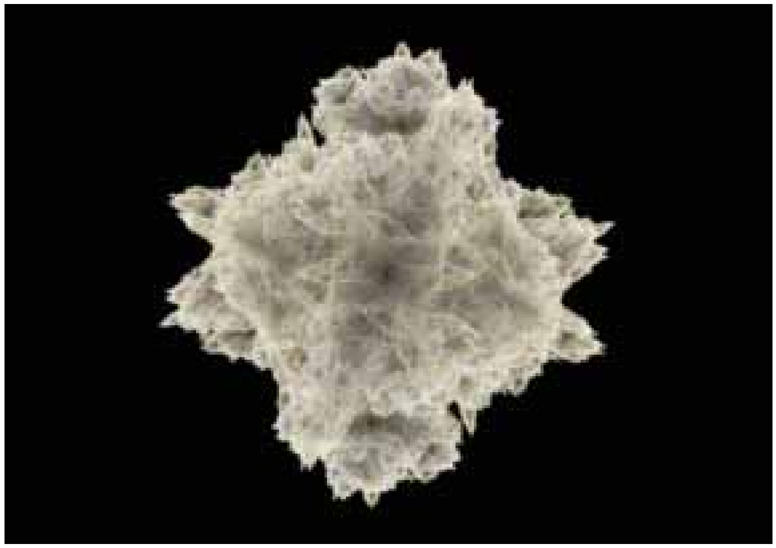


Figure 3.1
Soot particles, the result of incomplete combustion, are highly abrasive to internal engine components.

Soot is a natural by-product of the combustion process. After fuel is injected into the combustion chamber, it combines with oxygen and heat and ignites. As the piston reciprocates in its chamber, the rings spread soot particles into the oil. This process continues with normal engine operation and, left unchecked, the accumulated soot particles can grind away at internal engine surfaces, causing premature wear and component failure. Components susceptible to soot damage include cam lobes, valve lifters, valve stems and guides, piston rings, cylinder liners and bearings.

Oil formulated with quality dispersant additives can generally keep soot in the range of 0.002 to 0.5 µ suspended in the oil while the oil's detergent additives prevent the build-up of sludge and act as an acid neutralizer, keeping soot in the range of 0.5 to 1.5 µ in suspension. These anti-wear additives work by providing a sacrificial chemical-to-chemical barrier, but as the amount of soot suspended in the oil increases, their performance decreases. In other words, soot contamination leads to a direct drop in the anti-wear effectiveness of an oil's additives, increasing the risk of accelerated wear to critical engine components.

Soot Causes Wear

High levels of soot in the oil can lead to excessive and abnormal engine wear. Many current oil formulations extend oil life by holding higher concentrations of contaminants, including soot, in suspension in the oil. This creates an increased risk of wear caused by soot and minimizes the effectiveness of anti-wear additives. By-pass filtration significantly reduces the amount of wear-causing soot particles suspended in the oil to increase overall equipment operating life.

Oil Circulation System Basics

Automotive engines use oil circulation systems to lubricate engine components. Oil circulation systems are more effective at supplying oil to all the necessary parts than oil immersion systems, where components are immersed in an oil reservoir. Circulation systems also pressurize the oil, which increases the oil's load-carrying ability and allows it to act as an energy transfer media (i.e. hydraulic lifters). At 125 pounds per square inch (psi), an oil's viscosity increases by approximately 3 percent. It increases by 15 percent at 500 psi, and doubles at 3,000 psi.

The basic oil circulation system consists of an oil reservoir (oil pan), a ***pump*** (lobe or gear type) and ***plumbing*** to direct oil to engine components and allow it to return to the oil pan. A pressure-sensing device is usually incorporated to monitor the operation of the system. As the system generates pressure, a ***relief valve*** is used to prevent damage should over-pressurization occur. With a circulation system in place, it is relatively easy to incorporate an oil filtration system.

Oil Pressure

When it comes to fluid delivery systems, there are two prevalent terms relating to pressure. The first is ***system pressure***, which is the force applied by the fluid to any surface in the system and is most commonly reported in psi. The second type is ***pressure differential***, which is the difference between system pressures measured at two different locations within the system.

Any device in a system that offers restriction to flow will exhibit a pressure differential. The restriction to flow that may exist in filter media will result in a difference in pressure between the inlet and outlet sides of the media.

The pressure differential is determined by subtracting the filter's outlet pressure from its inlet pressure. Pressure differential is reported as pounds per square inch differential (psid) or delta pressure.

Oil Filter Life

As an oil filter collects more contaminants, its internal structure changes, which influences the relative importance of the various capture mechanisms that filter employs. For example, as the filter traps contaminants, an internal cake forms on the inside structure of the unit. This eventually causes the media to become so clogged that the motor oil can no longer flow through it rapidly enough to sustain normal engine operation.

Oil Filter Media

Common oil filter media, including cellulose, cellulose/synthetic blend, metal screen and full synthetic, were discussed in Section 1 of Filtration Fundamentals. Refer to that section for full descriptions of these media types.

The Four Particle-Capture Mechanisms

There are four basic ways oil filter media captures particles. Each capture mechanism is adept at capturing contaminant particles based on different particle characteristics, such as size or tendencies for movement.

Sieving

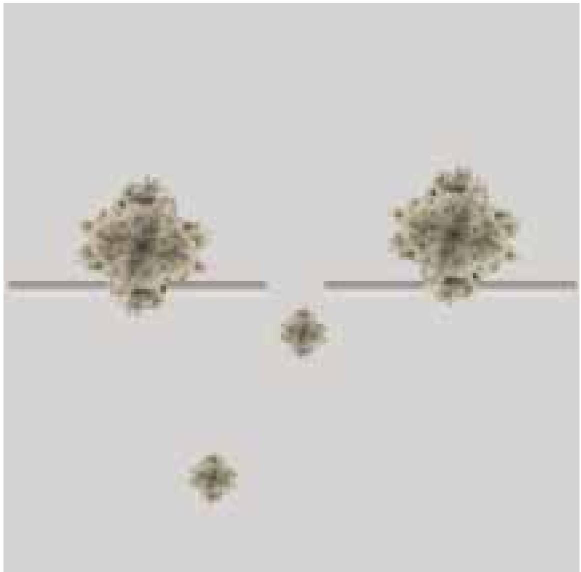


Figure 3.2
The sieving filtration mechanism

The ***sieving mechanism*** captures any contaminant that is larger than the spaces between the openings of the filter fibers, much like a window screen keeps out any insects or debris too big to fit through the small openings between the screen wires.

Inertial Impaction

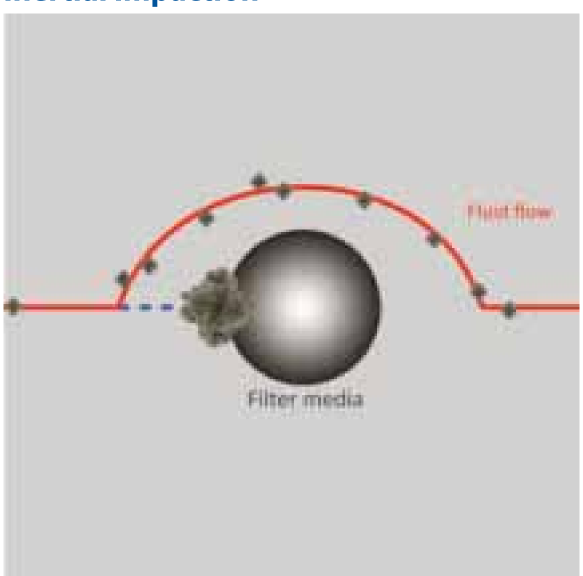


Figure 3.3
The inertial impaction filtration mechanism

The ***inertial impaction mechanism*** works on larger particles. Due to the size and mass of these particles, they continue on their original path rather than following the liquid stream. As the liquid flows through the abrupt directional changes of the filter media, contaminant particles follow their original path and become trapped by the filter media.

Interception

Figure 3.4
The interception filtration mechanism

The ***interception mechanism*** captures contaminants small enough to fit between the openings of the filter fibers, but large enough that part of the contaminant makes contact with the filter media.

Diffusion

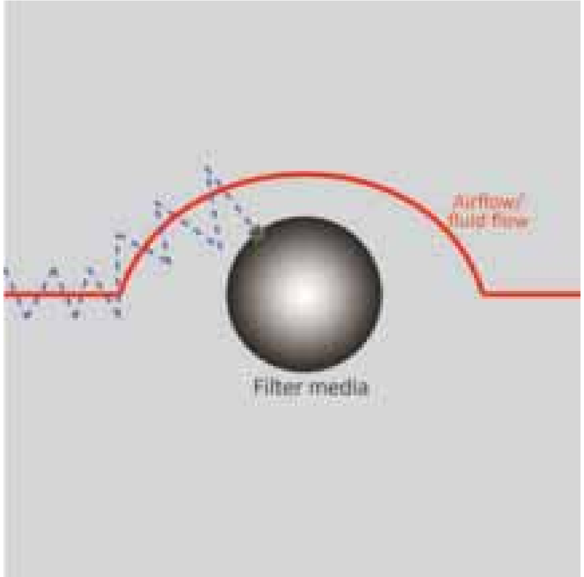


Figure 3.5
The diffusion filtration mechanism

The ***diffusion mechanism*** captures the tiniest of all contaminant particles. These minute particles, typically less than 0.001 mm, are so small that their movement operates in irregular paths referred to as ***Brownian Movement***.

While most bodies of mass will move in a straight line when a force is applied to them, these extremely small particles exhibit a zig-zag motion. Because they travel in a zig-zag pattern, they are easily captured by the filter media.

Section 3

Types of Oil Filtration Systems

Full-Flow Filtration System

The most common filtration system used today is the full-flow system. Within this system, the filter is placed in line between the pump and the engine. In full-flow systems, all oil undergoes filtration prior to being delivered to engine components.

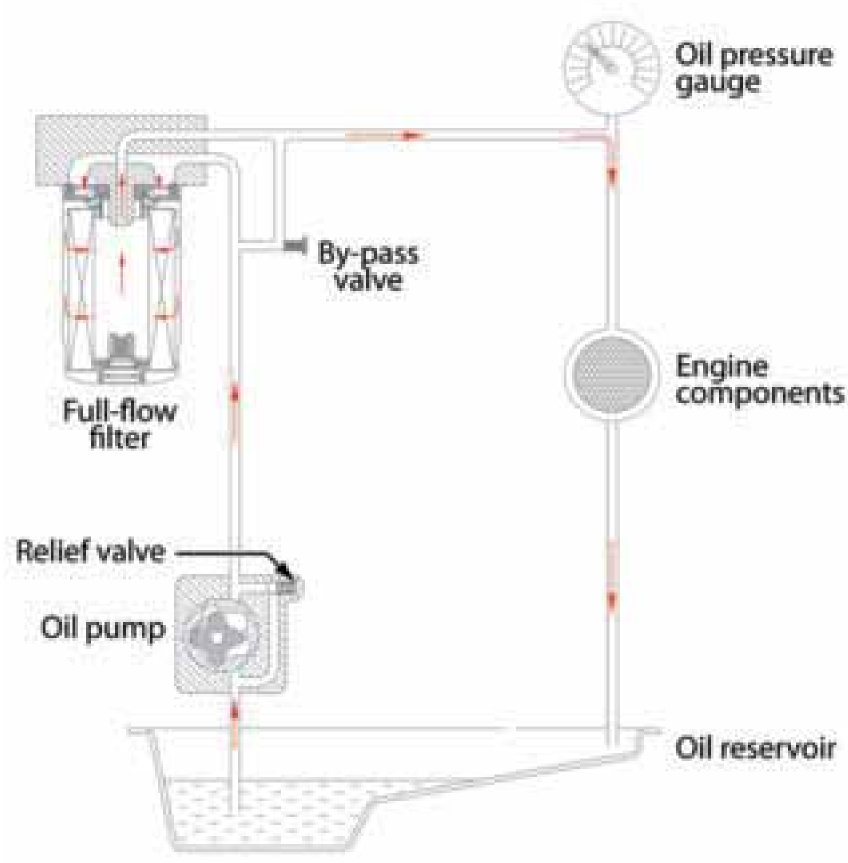


Figure 3.6
Full-flow filtration system

Filters in full-flow systems must feature media that is open and free-flowing enough to accommodate a high rate of flow and ensure engine components receive proper lubrication.

Because of the flow vs. efficiency compromise, full-flow filtration systems are designed to remove particles large enough to cause immediate damage (>40 µ). If the system were too restrictive, the full-flow filter could starve the engine of oil.

Full-flow oil filters can be divided into two design groups: cartridge and spin-on. The major difference is in their construction. In cartridge filters, the filtering element is replaced by disassembling an external housing. In spin-on filters, the filtering element is changed by replacing the cartridge and housing assembly by simply spinning the filter off of its mount.

Both types of filters are available in a variety of sizes. The largest are cartridge models. The filtration performance of either type depends solely on the media used.

Cartridge filters tend to have a higher initial cost than spin-on filters, but the cost to replace the element is lower. Cartridge filters are also more time consuming and messier to service than spin-on filters, so it costs more to have them serviced. Because spin-on filters are far more common in the transportation industry, this manual will concentrate on that style.

AMSOIL Ea Full-Flow Oil Filters

AMSOIL Ea Oil Filters' (EAO) synthetic nanofibers have a controlled size and shape to provide greater efficiency, capacity and durability than cellulose filters. AMSOIL Ea Oil Filters provide a higher level of engine protection and extended filter change intervals.

Ea Oil Filtration Media

AMSOIL Ea Oil Filter media is relatively thick and soft when compared to typical cellulose or cellulose/synthetic-blend media. It is backed with wire mesh to provide structural integrity within the filter. The multi-layered characteristic of the media selectively filters the various contaminants, providing higher efficiency and longer filter life.

Superior Construction

AMSOIL Ea Oil Filters are equipped with an oil-pressure relief valve to provide adequate oil flow under all operating conditions. Each heavy-duty housing has a draw steel double-crimp at the base with rolled-under seaming. A silicone anti-drainback valve prevents dirty oil from moving back into the engine. Ea Oil Filters are designed to provide maximum filtration while meeting the high-flow demands of modern automobiles.

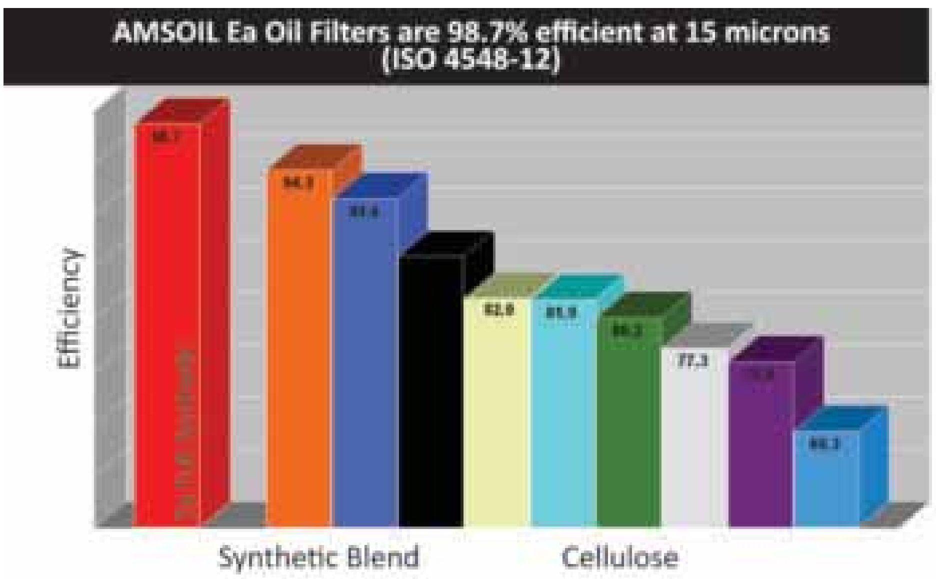


Figure 3.7
AMSOIL Ea Oil Filters are 98.7% efficient at 15 µ.

Absolute Efficiency

AMSOIL Ea Oil Filters have the best efficiency rating in the industry. Ea Oil Filters provide a filtering efficiency in accordance with industry standard testing (ISO 4548-12) of 98.7 percent at 15 µ, while competitive filters containing conventional cellulose media range from 40 to 80 percent.

Less Restriction

AMSOIL Ea Oil Filters provide significantly lower restriction than their cellulose counterparts. The exceptionally small spaces inherent to synthetic

AMSOIL Ea Spin-on Oil Filter Construction

nanofiber technology trap more particles of microscopic size while also providing more space for oil flow. Synthetic nanofibers also provide less restriction during cold-temperature operation by allowing oil to easily flow through the synthetic media, decreasing engine wear during warm-up periods.

More Capacity

A filter's capacity refers to the amount of contaminants it can hold and still remain effective. AMSOIL Ea Oil Filters have a greater capacity for small, wear-causing contaminants than competing filters do. In most applications, when used in conjunction with AMSOIL synthetic motor oils in normal service, Ea Oil Filters are guaranteed to remain effective for up to 25,000 miles or one year, whichever comes first.

AMSOIL Ea Spin-on Oil Filter Construction

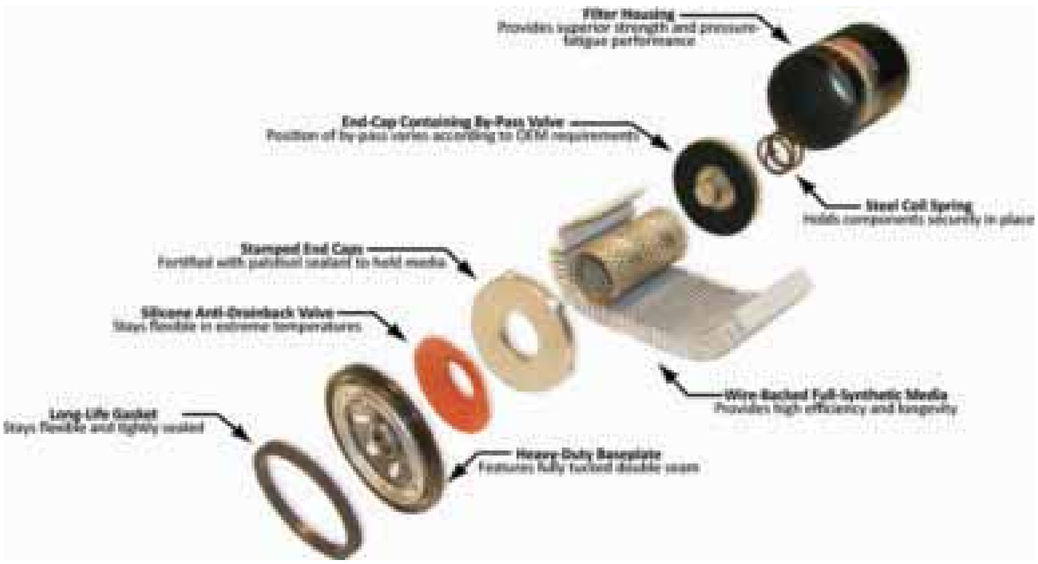


Figure 3.8
Detailed view and construction of spin-on oil filter

Filter Housing

Drawn metal vessel used to contain the oil. Also protects internal components from external impact.

Steel Coil Spring

Applies constant force on internal filter components, minimizing by-passing of unfiltered oil. It can be a helical spring or a stamped metal leaf spring.

By-Pass Valve

Safety valve that opens when the media is too restrictive to allow an adequate flow of oil (i.e. the media becomes saturated or at start-up with a cold, viscous fluid). Typically opens when an 8 to 12 psi pressure drop occurs across the media; however, 20 to 30 psid valves are not uncommon.

Filter Media

Generally a cellulose material, but may contain cotton, glass or synthetic fibers. Usually pleated to increase surface area, assisting in flow and capacity.

Anti-Drainback Valve

Prevents contaminated oil from draining back when the filter is mounted in an inverted or horizontal position. Minimizes time required to initiate oil pressure at start-up. May not be required on all models of filters, particularly when the filter is mounted with the base plate facing up.

Base Plate

Attaching point between the filter and engine; usually a heavy-gauge metal to minimize possible distortion during operation. Base plates are available in a variety of U.S. and metric thread sizes.

Base Plate Gasket

Seals the area between the base plate and the engine block. Available configurations are square-cut, O-ring and molded.

AMSOIL Advantage

- Selectively filter various contaminants
- Relief valve ensures proper oil flow under all operating conditions
- Silicone anti-drainback valve keeps dirty oil from re-entering the engine
- Maximum filtration while meeting high flow demands
- Lower restriction than conventional cellulose filters due to synthetic nanofibers
- Trap smaller particles
- Allow oil to easily flow through media during cold starts, providing lower restriction and reduced engine wear
- Greater capacity than competing filter lines

By-Pass Filtration

By-Pass Filtration Systems

By-pass filtration systems feature an additional filter, known as the by-pass filter, added to an existing full-flow system. In by-pass filtration systems, some of the oil is diverted to the by-pass filter and then returned to the system reservoir, by-passing the engine.

Oil diversion usually occurs at the oil-pressure sending unit and constitutes 5 – 15 percent of the oil pump output. A restriction orifice on the mount regulates oil flow and typically ranges from 0.5 to 1.0 gallons per minute, but could be as high as 3.5 gallons per minute. Oil flow regulation is necessary to prevent oil starvation downstream.

As previously discussed, particles in the 5 to 25 µ range inflict the most damage within an engine. Contaminants less than 5 µ will not cause catastrophic damage, but should be a concern due to their tendency to agglomerate into larger, more harmful particles. By-pass filtration systems are adept at containing particulates of this size. According to SAE Technical Paper 860547, minimum oil films on some engine components range from less than 1 µ to 3 µ. Contaminants that are less than or equal to the thickness of the oil film interfere with the lubrication process and increase engine wear rates.

Single Remote By-Pass System (Parasitic)

A parasitic system features a by-pass filter added to an existing full-flow circuit. Oil is diverted from the existing circuit, normally at the oil-pressure sending unit, directed to the by-pass filter, then returned to the system reservoir. The volume of oil diverted for by-pass filtration ranges between 5

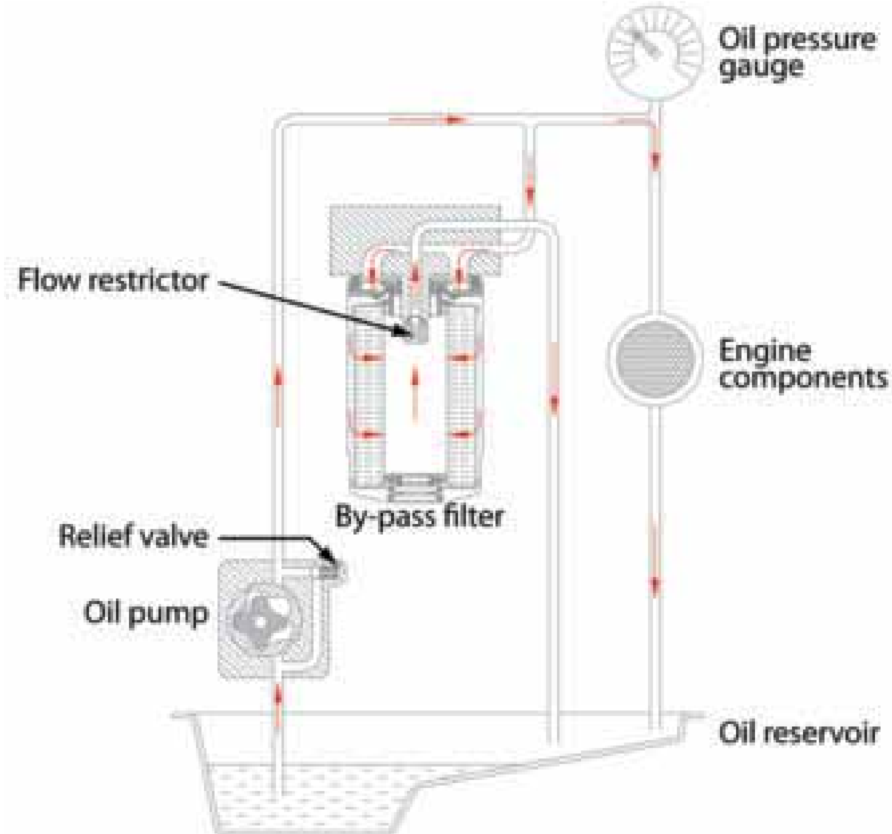


Figure 3.9
Typical by-pass filtration system

to 20 percent of oil pump output.

The AMSOIL Single Remote, DUAL-GARD and Heavy-Duty By-Pass Systems (BMK21, BMK22, BMK30) are examples of typical parasitic by-pass systems. Flow in these systems is regulated by a fixed restriction orifice retained in the mount. The Single Remote system has been developed for use on light- to medium-duty equipment, automobiles and light- to medium-duty trucks. The DUAL-GARD and Heavy-Duty systems were developed for larger equipment and heavy-duty trucks and buses.

Dual-Remote By-Pass System (Parallel System)

In a parallel system, the full-flow and by-pass filters are contained on a shared mount and fed by parallel ports. The oil has the option to flow through either filter but generally flows through the full-flow filter as it is less restrictive. Eighty to 90 percent of the oil flows through the full-flow filter and 10 to 20 percent through the by-pass filter.

In a parallel system, all oil subjected to either full-flow or by-pass filtration is directed to engine components. Because of this, there is no need to restrict the volume of oil flowing to the by-pass filter, so flow through the by-pass filter in a parallel system is generally 5 to 10 percent greater than in a parasitic system. The AMSOIL Marine System (BMK18) is an example of a typical parallel by-pass filtration system.

The original full-flow filter is removed from the engine and replaced with a spin-on fixture diverting the oil to a remote mount. At the mount, the oil is exposed to either full-flow or by-pass filtration and directed back to internal engine components. Remotely mounting the oil filters increases

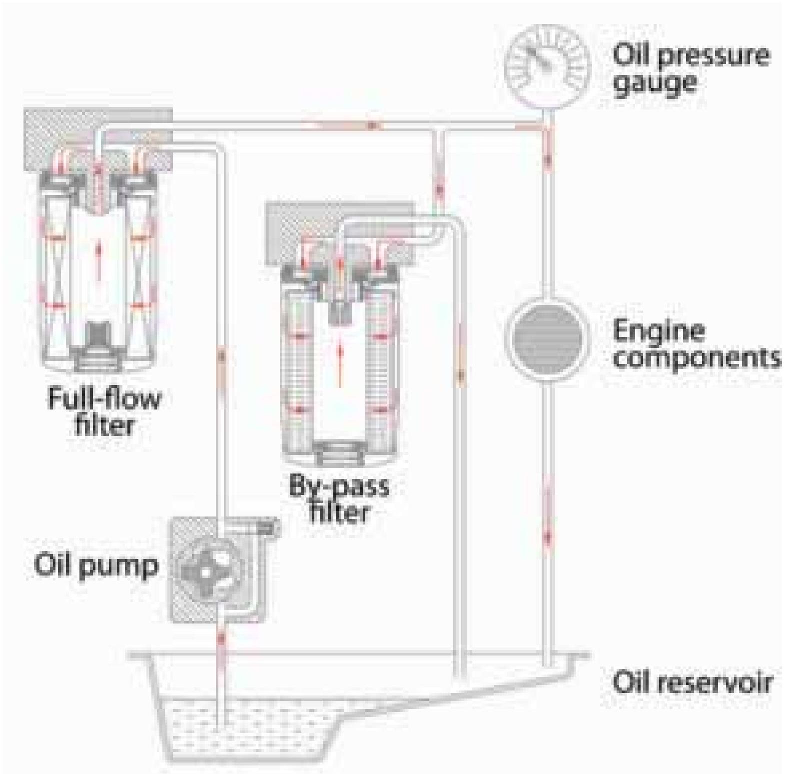


Figure 3.10
Single-remote by-pass filtration system (parasitic)

their accessibility and allows the use of larger filters.

AMSOIL provides dual-remote by-pass kits for specific applications. For example, the BMK23 is a universal system designed for most light- to medium-duty applications; the BMK25 is specifically for Cummins engines used in Dodge trucks (2003 and earlier); the BMK26 is for Ford 7.3L Power Stroke engines and the BMK27 is for GM Duramax engines. AMSOIL also

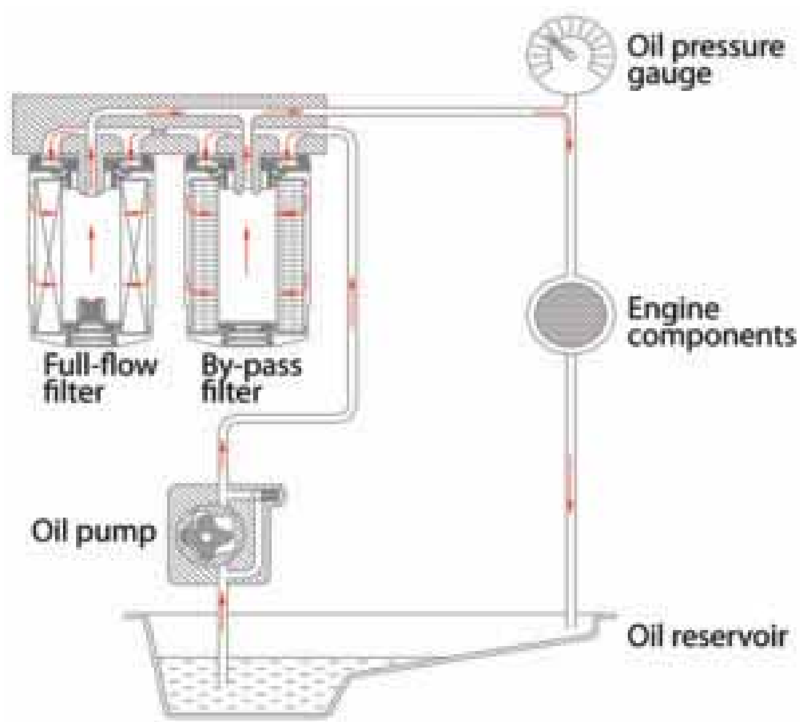


Figure 3.11
Dual-remote by-pass filtration system

offers a marine system (BMK18) developed specifically for light- and medium-duty marine applications.

AMSOIL Ea By-Pass Filters

AMSOIL Ea By-Pass Filters (EABP) are designed to withstand severe operating conditions while providing excellent engine protection. They feature a synthetic/cellulose media covered with a full-synthetic outer layer engineered for high efficiency and soot removal.

By-Pass Filter Efficiency

Figure 3.12 below illustrates AMSOIL Ea By-pass Filters' near-perfect efficiency rating.

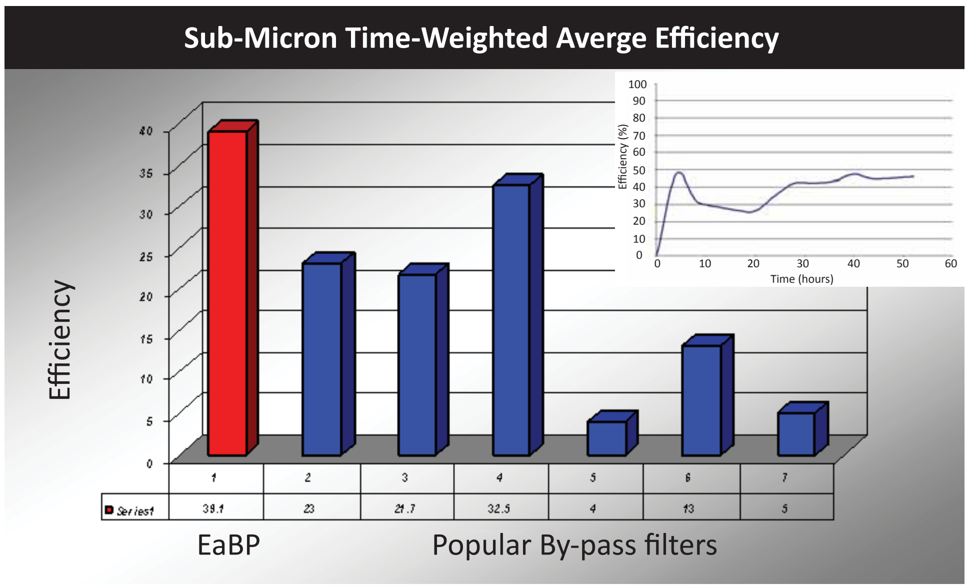


Figure 3.12
Sub-micron time-weighted efficiency performance for AMSOIL Ea By-Pass Filters

Ea By-Pass Vital Statistics

AMSOIL offers four by-pass filters: the EABP90, EABP100, EABP110 and EABP120. All vehicles and applications that can accept AMSOIL filter mounts can use Ea By-Pass Filters. AMSOIL recommends by-pass filters be mounted as close to vertical as possible. The filters are equipped with an anti-drainback valve in the event they are mounted at an angle.

Ea By-Pass Change Intervals

When used in conjunction with AMSOIL motor oil and an Ea or Donaldson Endurance Oil Filter, Ea By-Pass Filters should be changed every other full-flow filter change up to 60,000 miles. When used with other brands of motor oil or full-flow filters, Ea By-Pass Filters should be changed every other full-flow filter change. AMSOIL recommends using oil analysis when extending oil drain intervals.

AMSOIL Advantage

- Soot-removal device for excellent engine protection
  - Virtually 100% efficient at the removal of the most dangerous contaminant range (5 to 20 µ)
  - 39% efficient at the removal of soot contaminants less than 1 µ
- Patented filter-element construction
- Eliminate channeling and unfiltered oil from passing through
- Reduced filter change intervals for maximum cost effectiveness

Quality Construction
AMSOIL Ea By-Pass Filters have a marine powder-coated exterior. Their zinc-dichromate base plates increase rust protection and are compatible with existing AMSOIL by-pass filter mounts. Ea By-Pass Filters have a gasket and anti-drain valve. The two-stage, pleated and layered cellulose/full-synthetic media has an efficiency rating of 98.7 percent at 2 µ. The basic components of the can (base plate, and base plate gasket), are similar to those used in full-flow filters; however, several components differ.

Full-Flow Filters vs. By-Pass Filters
Full-flow filters are more open and free-flowing than by-pass filters because they must support the entire output volume of the oil pump. Full-flow filtration systems are designed for large-particle removal and the prevention of immediate damage and may permit small contaminant particles to reach engine components.

By-pass filters only manage a small percentage of the total volume of output from the oil pump, so they are able to use significantly denser filter media than that used in full-flow systems. Denser filtration media provides improved small-particle-removal efficiency and is more effective at reducing the long-term wear associated with smaller particles.

Full-flow filters and by-pass filters perform very different tasks, and their relative systems differ in the way filtered oil is distributed. In full-flow systems, filtered oil is directed to engine components. In by-pass systems, the filtered oil is returned directly to the oil reservoir.

Advantages to Combining Full-Flow and By-Pass Filtration
Combining full-flow and by-pass filtration in a single system can provide comprehensive wear protection against both large and small particles, and long- and short-term wear. This combination also increases filtration capacity and extends the overall life of both filters.

Full-Flow Filtration	By-pass Filtration
Free-flowing	Restrictive
Reduces immediate damage	Reduces long-term wear
Captures large particles	Captures small particles
Filtered oil goes directly to components	Filtered oil is returned to engine sump

Figure 3.13
Full-flow filtration systems vs. by-pass filtration systems

As a whole, the system is better able to maintain oil cleanliness and engine protection from both small and large particles. In addition, the increased oil volume required to sustain the integrated by-pass and full-flow system lowers operating temperatures and extends oil life.

By-Pass Filter Market
The by-pass market mainly serves heavy-duty applications, but its many technologies can also be applied to auto and light-truck applications. All AMSOIL products in this market are designed to provide high-efficiency filtration along with prolonged engine and oil life. Long-term benefits include reduced maintenance and operating costs.

Some by-pass units use angled spray jets or blades to spin the oil, creating centrifugal force which draws soot and contaminants from the oil and impacts them onto a special holding cup or surface.

Other by-pass filters use a form of highly compressed media, usually cellulose. By forcing oil to flow over, around and through the fibers, particles are trapped within the depth of the filter.

Another popular material used to make by-pass media is cotton fibers. Several by-pass makers use un-dyed, virgin cotton mill ends that are tightly compressed. Others use cotton twine and wind it in a criss-cross pattern to build up a depth of several inches. One manufacturer pioneered the use of stacked discs of cardboard.

Paper is an effective by-pass filter media, but it is most often used in full-flow oil and fuel filters.

By-Pass Filter Media

Ea By-Pass Filter media uses high-efficiency synthetic/cellulose-blended media for the inner layer of the element; highly efficient advanced full-synthetic media is used for the outer-layer element. It is very dense and provides exceptional small-particle removal efficiency.

Superior Construction

The superior construction of AMSOIL Ea By-Pass Filters provides better sealing and increased longevity along with superior corrosion resistance. Ea By-Pass Filters have a marine powder-coated exterior; and their zinc-dichromate base plates increase rust protection. Ea By-Pass Filters have a nitrile HNBR gasket and an orange silicone anti-drain valve. The two-stage pleated and layered cellulose/full-synthetic media has an efficiency rating of 98.7 percent at two microns.

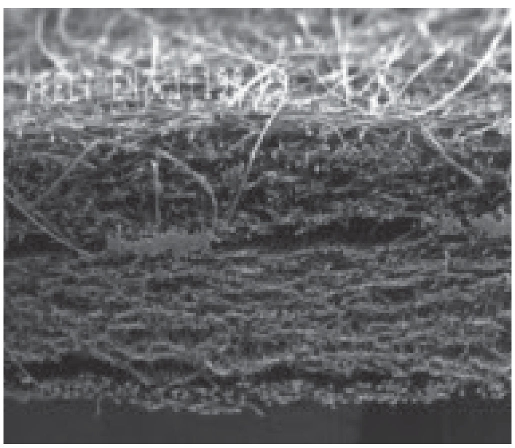


Figure 3.14
Dense Ea By-Pass Filter media

Oil Filtration Efficiency Terms

The following terms are commonly used to describe the efficiency of a filter, or how well it removes contaminants.

Nominal: Removes 50 percent of contaminants of the size or type indicated, or Beta 2.

Absolute: Removes at least 98.7 percent of contaminants of the size or type indicated, or Beta 75.

Micron Rating: No universally accepted definition. If a filter’s micron rating is not correlated to its efficiency percentage, the micron rating offers no value in understanding the performance of the filter.

Typical Full-Flow Filter Efficiency: The efficiency of typical full-flow automotive oil filters is nominal (50%+) at 40 µ. High-performance automotive oil filters typically offer a nominal efficiency at 20 µ. Significant removal of particles 20 µ and smaller can only be obtained using some form of by-pass filtration.

Beta Ratios & Filter Efficiencies

Specific testing procedures are used to evaluate the performance of oil filter media, mainly in the areas of efficiency, capacity and durability. AMSOIL filters are tested using a multi-pass test, also known as the **beta ratio** test (β), to determine the contaminant-removal efficiency of the filter media, and to determine if the media meets AMSOIL standards. The beta ratio test is a universally accepted method for determining filter media performance.

Figure 3.15 displays the beta ratio values with their correlating capture efficiencies. A beta ratio value of 2.0, for example, is equal to 50 percent contaminant-removal efficiency. AMSOIL requires that all AMSOIL Ea Filters have a beta ratio of 75.0 or higher, meaning that the filter is able to hold 98.7 percent or more of contaminants of a known size or larger. Notice that beta ratios above 75.0 indicate little improvement in filtration efficiency; beta ratios in the thousands are possible, but are more misleading than informative.

What does Ea Mean?

Absolute efficiency (Ea) describes filters that pass the multi-pass (beta ratio) test with a contaminant-removal efficiency rate of 98.7 percent (75.0 β) or better.

Beta Ratio	Capture Efficiency
1.01	1.0%
1.1	9.0%
1.5	33.3%
2.0	50.0%
5.0	80.0%
10.0	90.0%
20.0	95.0%
75.0	98.7%
100	99.0%
200	99.5%
1000	99.9%

Figure 3.15
Beta ratio and capture efficiencies

AMSOIL Ea Filters are evaluated with the beta ratio test in order to validate their high efficiency performance and demonstrate their superiority to consumers.

In the test, fluid containing particles of a known size is filtered through the test media. At specific intervals, particles are captured and counted on both sides of the filter media. The upstream and downstream concentrations of particles are used to calculate the beta ratio (numbers of particles upstream are divided by the numbers of particles downstream

Figure 3.16
Beta ratio accurately compares the size and quantity of particles upstream and downstream of the filter.

For instance, if 1000 2 µ particles are captured upstream of the filter media, and 13 2 µ particles are captured downstream of the filter media, the beta ratio would be expressed as, βx=1000/13= 76.9 where x represents the size of the particles measured. A Beta ratio of 76.9 indicates the filter removed over 98.7 percent of the contaminants 2 µ or larger, which meets AMSOIL Ea standards.

Industry-Accepted Standards for the Evaluation of Oil Filters

There are many terms and test methods used to indicate the performance of a filter. Today, the most widely used test method for oil filters is the International Organization for Standardization (ISO) test method ISO-4548-12 (Methods for Testing Full-Flow Lubricating Oil Filters for Internal Combustion Engines).

ISO 4548-12 is derived from the ISO standard for multi-pass filter testing (ISO 16889), which is based on testing of hydraulic filters. This test requires filter manufacturers to determine the average particle sizes that yield beta ratios equal to 2, 10, 75, 100, 200 and 1000 using the multi-pass test approach.

The multi-pass test must contain on-line, liquid, automatic optical particle counters and be calibrated using certified calibration fluid with a known particle size distribution. Particle counts are taken upstream and downstream every minute of the test. Because the new standard gives a better interpretation of a filter's overall performance, AMSOIL has chosen this method (ISO 4548-12) to review the performance of its full-flow and by-pass filters.

An older test using multi-pass protocol is SAE J1858. This test also reviews the ability of a filter to remove contaminants of a specific size from the fluid stream at a specific moment in time. The test can be repeated to suggest efficiencies over the life of the filter. Results are reported as a ratio between the number of particles of a given size entering the filter and the number of the same size particles exiting the filter (beta ratio).

Finally, SAE HS J806B reviews the ability of a filter to remove a known contaminant from the fluid stream over a period of time. Results are reported as the percent of contaminant (by weight) removed over a period of time (time-weighted efficiency). Capacity (life) is determined by noting the amount of contaminant required to increase the resistance across the media to a given level. Capacity is reported in grams of contaminant. As the contaminant used varies in particle size and the efficiency is reviewed over time, this test method predicts how a filter will perform in a given application.

Note: Filters' test performances can only be compared when they have been obtained using the same test method.

Filter Lookup Resources

The appropriate filter for a given application can be determined using either the Online Product Application Guide at www.amsoil.com, or the AMSOIL Filter Application & Cross-Reference Guide (G3000).

The filter catalog deals specifically with automotive and light-duty truck applications, but also contains filter cross-reference by original equipment and competitive manufacturers' filter numbers, service recommendations and instructions, dimensional information on all AMSOIL Ea Air and Oil Filters, warranty information, cabin air information and a complete heavy-duty cross-reference section. Whether searching by vehicle identification or filter cross-reference, the filter catalog is easy to use.

For vehicle identification, simply find the page listing the manufacturer and model-year of the equipment, then find the model and engine size.

For cross-referencing, locate the number of the filter currently being used. Ignore opening zeroes, look up the first digit or letter, then look up each additional character. Remember, each number is sorted character-by-character, zero through nine, then A through Z.

The filter catalog is updated and reprinted annually. Between updates, current information is listed in the AMSOIL *Action News*, Hotwire and the AMSOIL website.

The Online Product Application Guide at www.amsoil.com contains all AMSOIL application guides, including the PowerSports and Motorcycle Application Guide, Heavy-Duty Application Guide, AMSOIL Master Filter Cross-Reference, Gear Lube Application Chart, Two-Cycle Applications Chart and VIN Code Lookup.

All that is required to determine which filter, engine oil and other lubricants a vehicle requires is the make, model, year and engine size. Lube capacity, spark plug and wiper blade information are also supplied.

The Master Filter Cross-Reference is a useful tool to determine the correct AMSOIL, Donaldson or WIX filter required for specific applications. Choose the applications of the vehicle or equipment and enter the cross-reference part number with no dashes, slashes, spaces or other punctuation. If no AMSOIL, WIX or Donaldson filters appear, contact the AMSOIL Technical Service Department at (715) 399-TECH for additional assistance.

Heavy-duty applications such as class 6, 7 and 8 trucks; construction equipment; generators; buses and other off-road equipment have a separate lookup. The lookup is designed to determine the filter by inputting the type of engine or engine number, or type of equipment. The lookup page also includes a filter cross-reference. Due to the almost

Figure 3.17
Filter Application Cross-Reference Guide (left) and the AMSOIL website (right) contain information pertaining to filter cross-reference and applications

limitless number of heavy-duty applications, it might be more convenient to obtain the filter number the equipment presently uses and cross-reference it to the equivalent Donaldson filter.

Oil Filtration Tips

Filter Installation

When installing a new oil filter, note that the sealing gasket can be distorted by the rotation of the filter against the stationary engine block. This results in stress on the gasket and reduces its potential life. It can also be the cause of oil leakage. To minimize this stress, follow the installation instructions below.

1. Prior to installing the new oil filter, use a lint-free cloth to clean the filter sealing surface on the engine block.
   Make sure the old filter gasket has been removed from the area.
2. Follow the oil filter installation instructions located on the oil filter. These instructions can also be found on the filter box.
3. Once the oil filter has been correctly installed, start the engine and check for leaks.

Over-Pressurization

It is not unusual to encounter a filter that has been ballooned out. Many people will conclude that the filter is defective; however, the problem usually has nothing to do with the filter. Instead, it is an indication that there is a malfunction in the oil pump pressure relief valve.

As previously discussed, all automotive oil supply systems have the ability to produce excess oil pressure (volume). This ensures that the system can compensate for things like component wear. To ensure that this pressure does not damage components, a pressure relief valve is designed into most oil supply systems. If this valve sticks in the closed position, pressure can build to the point where the filter will be damaged.

To get an idea of the amount of pressure that can be tolerated in these systems, keep in mind that 250+ psi is required to distort an AMSOIL filter. If the pressure relief valve should stick in the open position, over-pressurization will not occur, but overall oil pressure will be greatly reduced at lower rpm.

In a worst-case scenario, over-pressurization can result in the oil filter being blown off the engine. However, in most cases, the outward signs of such a problem are not as noticeable. Some tell-tale signs include bulging of the filter dome or distortion of the base plate. In this case, the base plate is no longer perpendicular to the filter can. In either case, the filter should be replaced and the cause of the damage should be corrected.

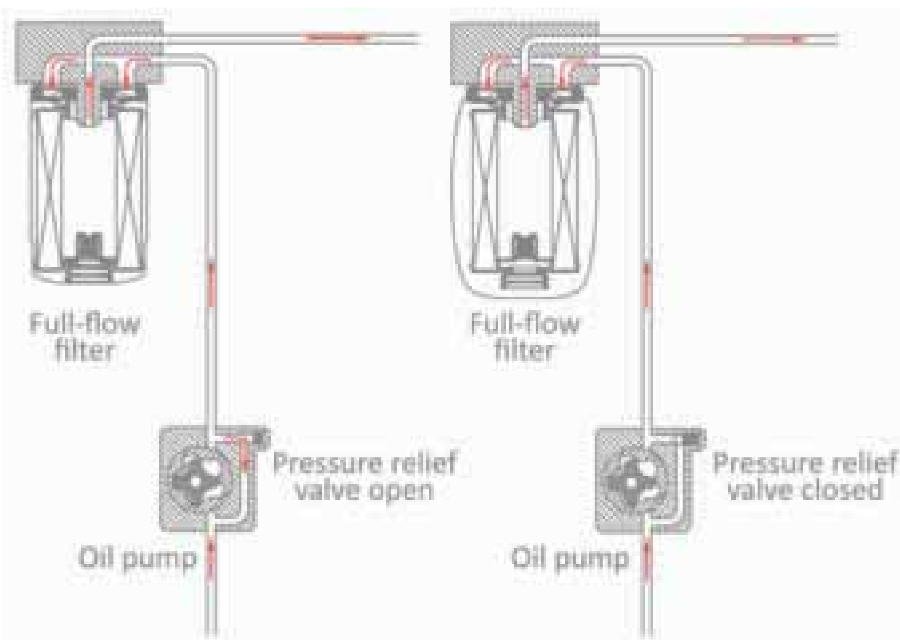


Figure 3.18
Over-pressurized oil filter

Section 3 Review Questions

1. List the four main functions of oil in an engine

____

____

____

____

2. What are the two main sources of engine oil contamination?

____

____

3. Conventional oil filtration is good for solid contaminants, how are contaminants like fuel or acids usually handled?

____

____

4. Soot is abrasive.

True or False

5. Pressurizing oil increases its ______________ ______________ability.

6. What are the three basic components of an oil circulation system?

____

____

____

7. What is one way today's oil manufacturers extend oil life?

____

____

8. To prevent damage resulting from over-pressurization, most oil circulation systems incorporate a _________________________________.

9. ________________________is the force applied to any surface in the system by the fluid.

10. ________________________ is the difference in system pressure measured at two different locations within the system.

11. The ___________________ capture mechanism works on the smallest particles in the oil stream.

12. Full-flow filtration systems are better at capturing __________ particles

than __________ particles.

13. Full-flow filtration is designed to filter particles greater than _________ µ.

14. By-pass filtration is designed to filter particles less than __________ µ.

15. ______________ _____________ is recommended when extending oil drain intervals.

16. The ___________ ___________ applies force to the media to compensate for changes in media height, preventing media channeling.

17. Current by-pass filters mostly use ____________ ____________ media.

18. Performance differences between cartridge and spin-on oil filters are due to filter design.

    True or False

19. ________________________ filters are the most common type of filter construction used in the transportation industry.

20. The anti-drainback valve's purpose is to minimize dry starting.

    True or False

21. When used in conjunction with an Ea or Donaldson Endurance Oil Filter, Ea By-Pass Filters should be changed every other full-flow change or 80,000 miles.

    True or False

22. What does the beta ratio indicate?
    ____

    ____

23. The beta ratio is determined by ___________________________________
    ____.

24. Using the beta ratio, a 4 µ filter with a beta rating of 65 means what?
    ____

    ____

25. List two ways in which air and oil filters differ.
    ____

    ____

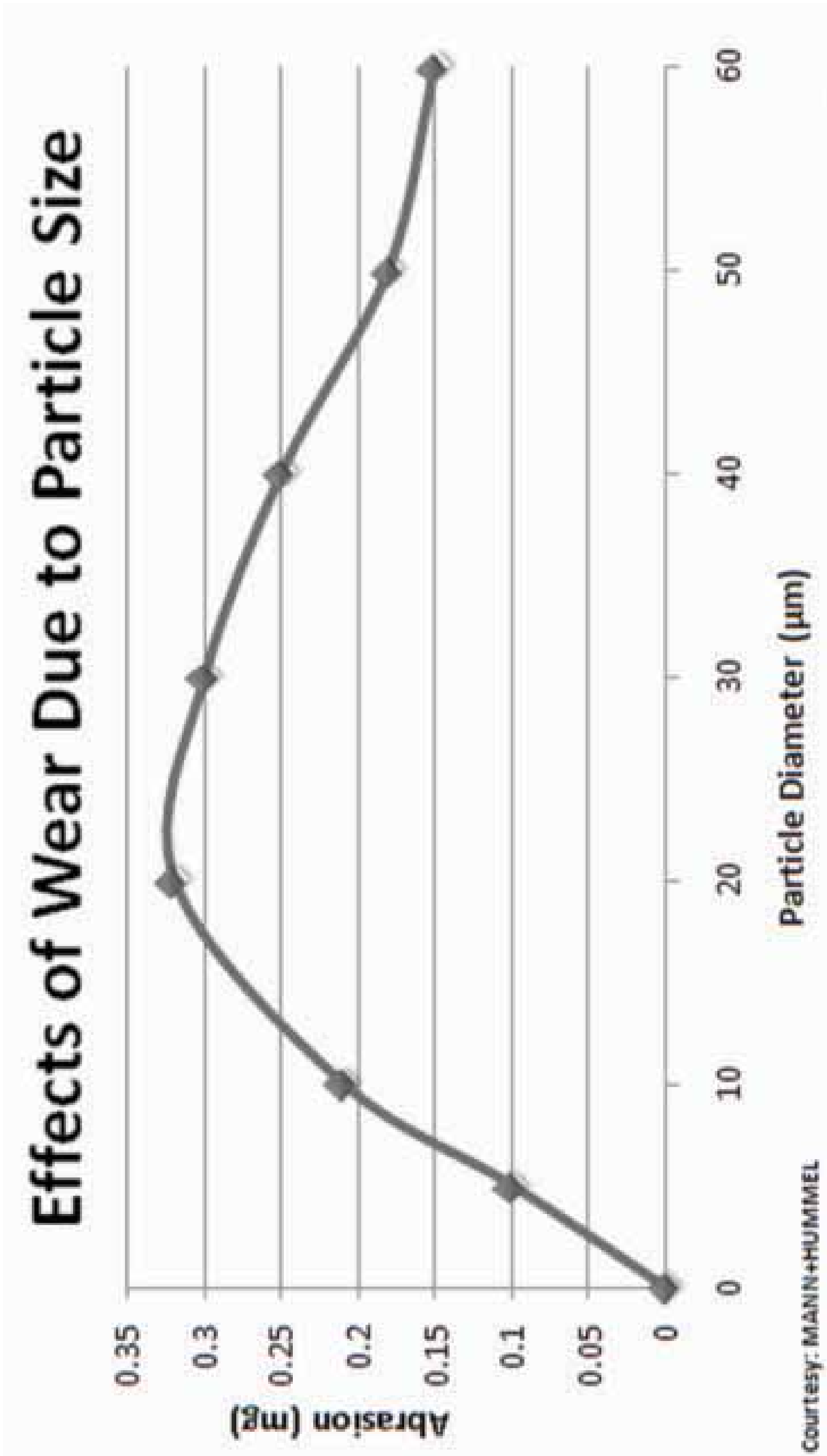
Section 3

Appendix

Major Causes of Premature Bearing Failure Chart

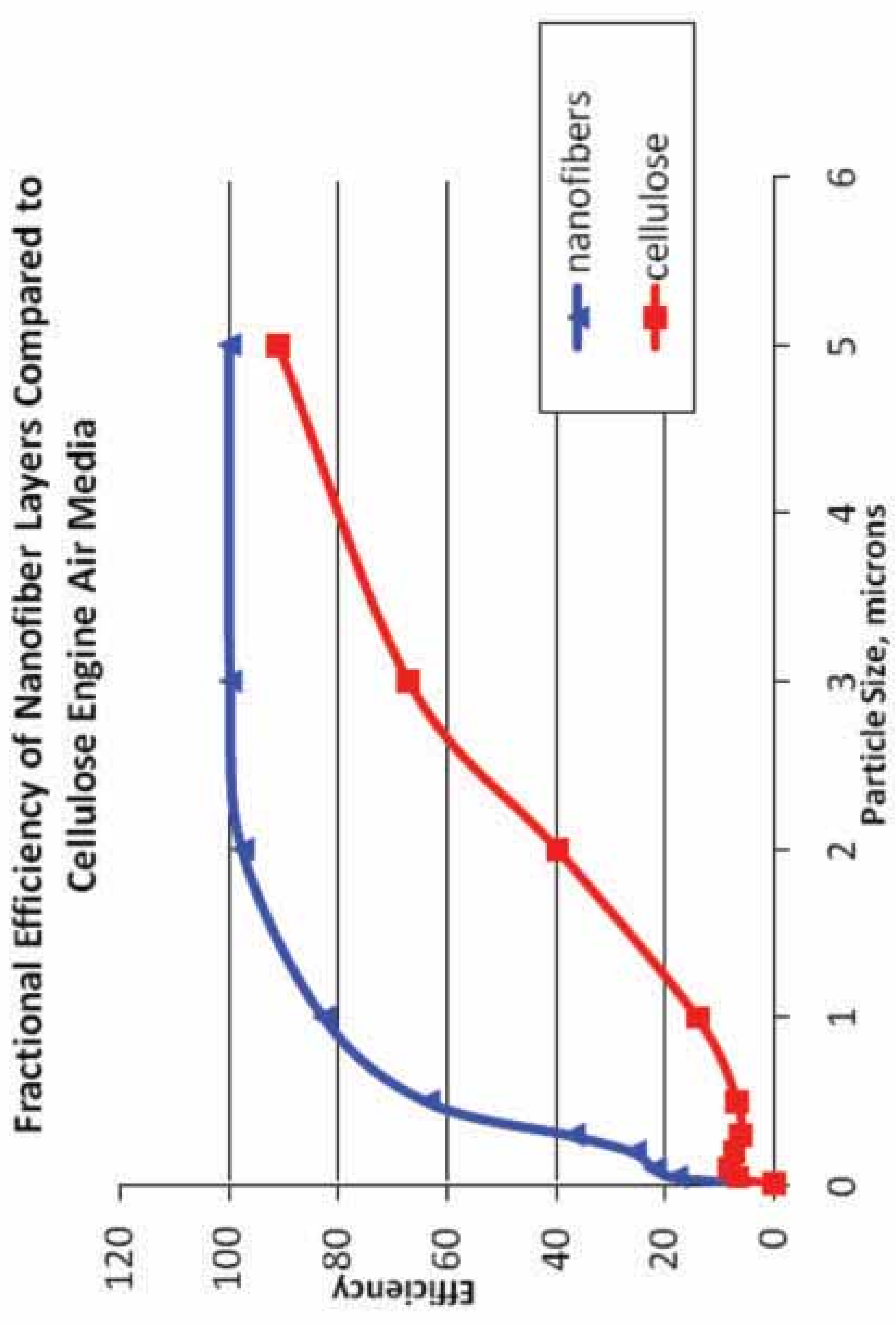
Major Causes of Premature Bearing Failure	
Dirt	49%
Assembly	13.4%
Misalignment	12.7%
Insufficient lubrication	10.8%
Overloading	9.5%
Corrosion	4.2%
Other	4.5%

Effects of Wear Due to Particle Size Graph



Appendix

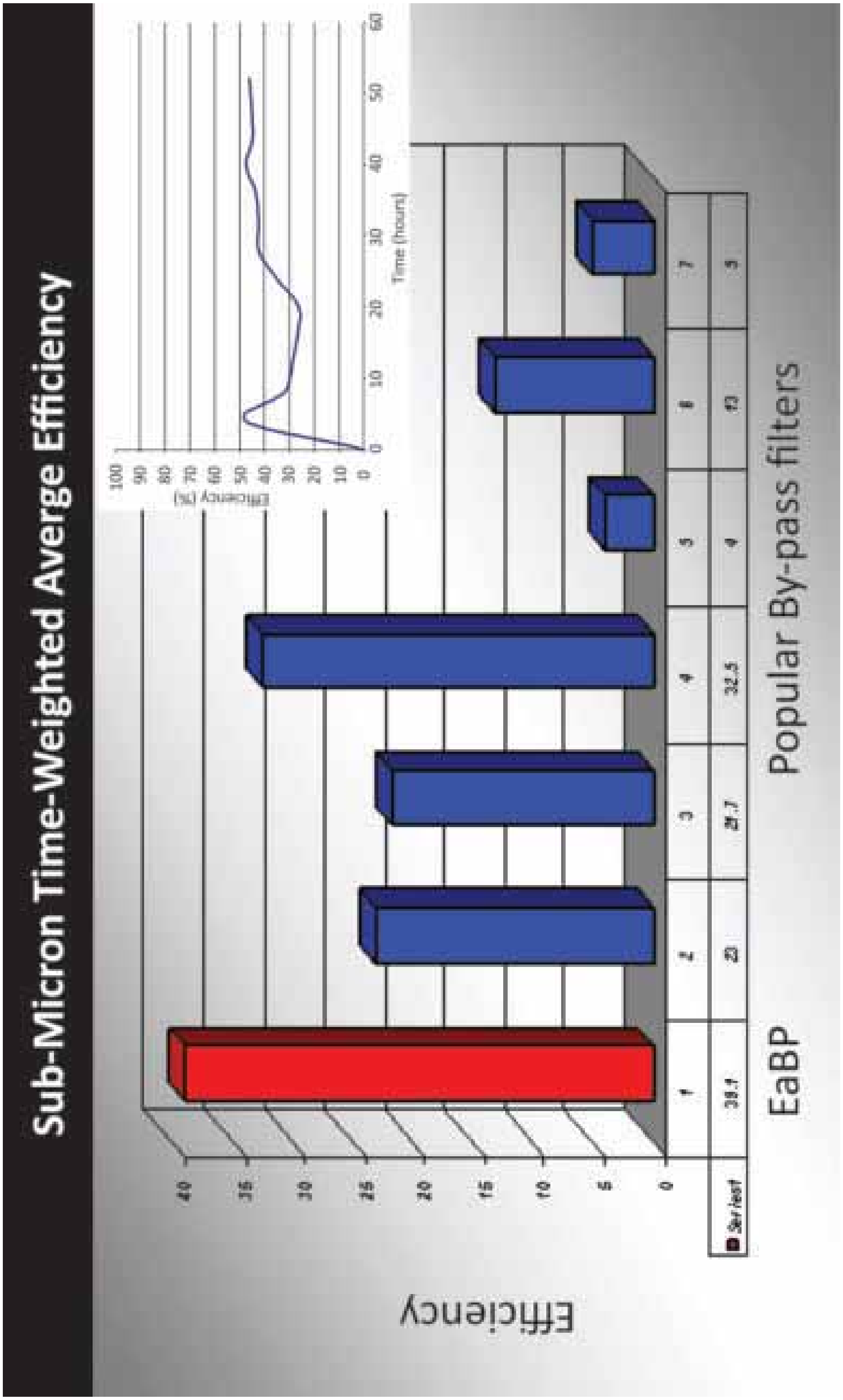
Fractional Efficiency of Nanofiber Layers Compared to Cellulose Engine Air Media



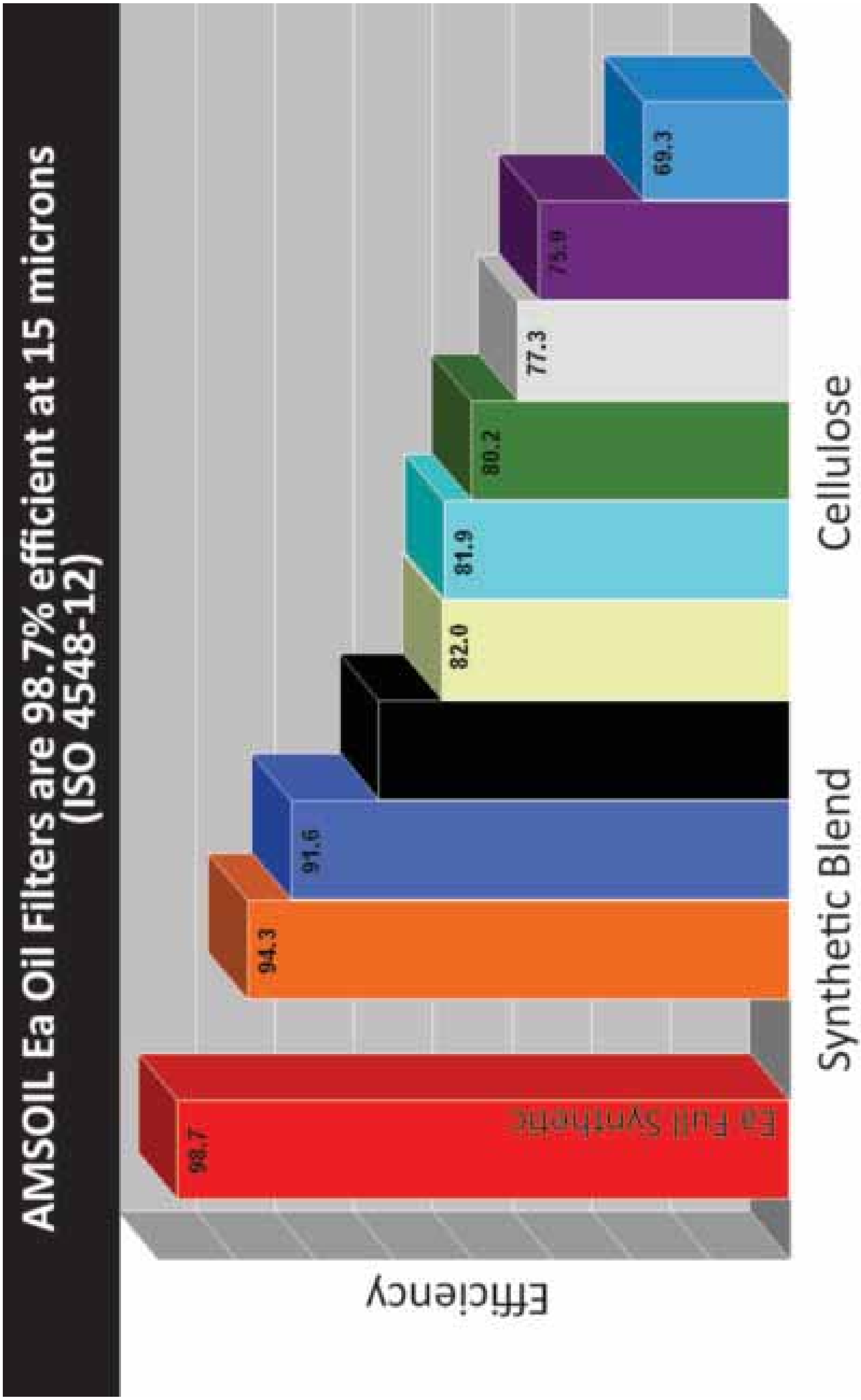
Beta Ratio - Capture Efficiency Chart

Beta Ratio	Capture Efficiency
1.01	1.0%
1.1	9.0%
1.5	33.3%
2.0	50.0%
5.0	80.0%
10.0	90.0%
20.0	95.0%
75.0	98.7%
100	99.0%
200	99.5%
1000	99.9%

Sub-Micron Time-Weighted Average Efficiency Graph



AMSOIL Ea Oil Filters Efficiency Graph



Appendix

Notes

Notes

The First in Synthetics®