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A Comprehensive Technical Handbook on Motor Oil, Lubrication and Filtration Authored by:

Dave Mann: Lubrication Specialist and Truck/Automotive Engineer

This book will quickly become your complete technical handbook, written in layman's terms, on motor oil and filtration. It will also provide insight into what various vehicle and equipment manufacturers and service centers do not mention about synthetic lubricants. If after searching all over for answers and asking numerous "experts" you're still confused, this book will be a welcome addition to your knowledge base.

With my extensive industry experience as a Lubrication Specialist and Truck/Automotive Engineer, I clearly identify the facts so you can make an informed decision. The facts identified are supported by undisputable scientific and engineering tests and data, both in the lab and in the field.

You spend a lot of money on your new vehicles and other equipment and **you need concise, factual answers on all aspects of petroleum motor oils, synthetic motor oils and oil filtration from an engineer and industry expert.** I set the record straight and clearly present the information explaining the differences between petroleum motor oil and synthetic motor oils as well as detail the facts on just about every possible vehicle lubrication and filtration question you could have.

Synthetic motor oil use is one of the fastest growing automotive maintenance and performance products on the market, yet with all these people seeking knowledge and advice, there are very few people that are knowledgeable enough and qualified to provide advice on not only synthetic motor oils but petroleum motor oils as well.

Consumers often ask people they think are qualified and get an opinion, not supported by any data, that they believe is accurate, and then make critical decisions based on this inaccurate advice/opinion. I deal with this every single day and it is my intention to help people learn the facts in an easily understandable format and make myself available to personally answer their specific questions with concise, factual answers supported by data.

In this day and age of high-performance synthetic lubrication it just doesn't make any sense to use petroleum oil, yet every day millions of people still do, because they don't know the facts. After years of trying to convince certain manufacturers to use a high quality extended drain interval synthetic in the U.S. I have concluded that it will most likely not happen due to reasons other than technical and engineering issues. In my opinion these issues center around cost, profits, service work, parts sales and product life cycle issues.

Therefore, I have written this comprehensive book so people all over can benefit from this valuable information. This book will provide complete technical information on critical lubrication principles, synthetic and petroleum motor oils and filtration in an easy to understand format. **You do not have to be a technician or engineer to benefit from this book. I have carefully written each section to provide the most important facts and details that you need to know in an easily understandable format.**

My Guarantee to You

After completion of this book you will have learned everything you need to know about petroleum motor oil, synthetic motor oil and filtration and will be able to immediately benefit from the information gained. Your vehicles and equipment will last longer and perform better and you will save thousands of dollars in oil changes, repairs and new vehicle purchases in addition to large time-savings both now and into the future. **In addition you will also have access to my toll free number and email for any technical questions.**

The industries that survive on performing regular oil changes or 3000 mile-oil changes are counting on you not learning what is inside this eye opening extremely informative technical book authored by myself, Dave Mann, a leading Lubrication Specialist and Truck/Automotive Engineer.

I've spent many years in the OEM (Original Equipment Manufacture) vehicle industry while being directed to engineer components and systems to meet specific cost and performance targets. In order to meet these targets I felt like my creativity and durability mindset was being stifled. I prefer to engineer things so that as long as they are properly maintained and serviced the parts will not wear-out, regardless of how long the vehicle is kept or how many miles it has on it.

I felt like I constantly had to balance cost, weight and performance to meet specific targets, which I personally did not agree with. My primary goal is to achieve exceptional durability regardless of cost or weight and that customers would pay extra for this exceptional durability. However, since I did not have influence to direct engineering in this manner **I utilized synthetic lubrication to achieve my objectives**. With synthetic lubrication I found I could keep a vehicle in service far beyond what is considered a normal service life and at the same time increase performance and protection and save significant amounts of time and money in the process.

I have vehicles and equipment ranging from the latest gas and diesel trucks and cars to older trucks and farm tractors as well as snowmobiles, motorcycles, watercraft, generators, chain saws, lawn equipment, and numerous other types of power equipment. Utilizing synthetic oil and superior filtration in this equipment over the years has been the prime reason for it's incredible performance, longevity and lack of major repairs whether it be engines, transmissions, axles, transfer cases, wheel bearings, u-joints, ball joints or tie rods or any other component or system which requires lubrication.

Now, don't get me wrong here. I'm not saying to keep a vehicle forever. New models and technical and performance advances come out which make it attractive to purchase a new vehicle periodically. My theory is that it should be up to you to determine how long you keep a vehicle, not when it has a certain amount of miles on it things start to wear-out and need replacement, often costing significant amounts of money up to the point that the owner gets tired of it and trades it in or sells it and purchases a new model to avoid the mounting repair costs and then starts the cycle all over again, along with a new hefty monthly payment. Wouldn't it be nice to pay that vehicle off and then continue to drive it for a long time after that, without worrying about major repairs and associated costs?

As you can probably figure out, I am a firm proponent of synthetic lubrication. With the cost of vehicles these days it is imperative to seek out superior synthetic lubrication and filtration products in order to achieve maximum performance and significantly decreased wear rates. My book explains every aspect of lubrication and filtration so that you can learn and easily understand the information presented and make your own informed decisions based on test data and scientific and engineering facts.

Special Bonus Section

How to understand, eliminate and prevent the most common brake problem: brake pedal pulsation and vibration. I review proven expert service procedures that you need to know whether you service you vehicles brakes yourself or pay to have them serviced. I completely debunk the common myth that brake rotors "warp" and explain what really happens and how it can be corrected without costly repairs and how to prevent it from occurring in the future. I also provide you with some proven methods in order to increase the longevity and performance of your cars and trucks as well as important information on brake lining material descriptions that manufacturers commonly use to promote their brake linings.

1. BASIC LUBRICATION PRINCIPLES, FRICTION AND WEAR-IN

Before one can properly select a lubricant for a specific application some basic theory must be understood. When one surface moves over another there is always some degree of resistance to movement. This resistance to movement is called friction. Friction can manifest itself in varying degrees from smooth easy sliding to uneven erratic movement, which can generate excessive heat and cause damage to the moving surfaces.

Friction is good when it causes the brakes and tires on cars and trucks to stop the vehicle or when it keeps our shoes from slipping on wet surfaces, yet friction is bad when it causes heat, wear and reduced energy in an engine, gearbox, transmission or piece of equipment.

Lubrication is simply the use of a material to improve the smoothness of movement by reducing friction. The immediate result is reduced wear and reduced heat generation. There are numerous types of lubricants but for this book the main consideration is synthetic and petroleum motor oils, ATF and gear lubes as related to automotive, motorcycles, recreational vehicles and other equipment.

The coefficient of friction between two moving materials is defined as mu and changes with load and speed. The force needed to start the movement is defined as static friction and is typically always greater than the dynamic friction, which is the force required to keep the two materials moving at the same speed once initial movement has started. Different oils and different materials and loading conditions can create vastly different coefficients of friction that can affect performance and longevity of an engine and other mechanical components. **A few basic key functions of a motor oil is to reduce friction under all extremes of operating condition, prevent corrosion of internal engine components and provide for cooling via transfer of heat**.

When it comes to reducing friction (as well as preventing corrosion and providing effective heat transfer) I am a firm believer in synthetic lubrication. Here’s the basics of why I say that: when using a petroleum oil, under certain conditions, the lubricant film can be either too thin, thus allowing metal-to-metal contact, or too viscous which causes high internal friction within the layers of the oil. The key is to select an oil that is thin enough to have a low internal friction coefficient, yet still high enough to effectively separate two metal surfaces under all operational conditions and prevent excessive wear and heat generation. The facts prove that synthetic lubrication achieves both of these objectives while with petroleum oil there can be a compromise. The uniform molecular structure of synthetic lubricants allow it to flow freely for low internal friction, yet still effectively separate two metal-to-metal contact surfaces under normal and extreme operating conditions and significantly reduce internal wear.

When you look at two metal surfaces, such as piston to cylinder, and visually see that they appear smooth what you are seeing does not accurately reflect reality. When viewed under a high-powered microscope even the smoothest machined surfaces are rough and are viewed as millions of peaks and valleys. These peaks are under extremely high loading and need to wear-in (commonly called break-in) on a new engine. However, there is much discrepancy among automotive and motorsport enthusiasts as to how long of a time period is required for engine wear-in and whether or not petroleum oil must be used for the initial wear-in.

The time required for wear-in, before converting to synthetic oil, on a new production manufactured engine is very minimal and typically occurs during the hot run test at the engine manufacturer and also on the chassis rolls in the assembly plant, while driving the vehicle around the storage yard, railhead, dealers lot and test drives. Babying a new production car for many thousands of miles to "break it in" is no longer necessary, as it was many years ago. There are also a several models of high performance production vehicles that come factory fill with synthetic oil, further verifying the fact that petroleum oil is not required to wear-in an engine.

My recommendation is to run a short cycle of the manufacturer's installed petroleum oil, then drain the oil and remove the original filter and you're ready to install a premium quality synthetic motor oil and oil filter. This short cycle of petroleum oil can be at your first scheduled oil change, or sooner if you prefer. A film of oil is needed between the two surfaces to keep them from welding together yet, still allowing for adequate wear-in. This film of oil can be either a petroleum oil or a synthetic oil. It is important to understand the fact that synthetic oil will not prevent an engine from wearing in. With today's high tech manufacturing technology, designs, equipment and materials wear-in time can be kept to an absolute minimum. Therefore synthetic oil can be installed as either a factory fill by the manufacturer or installed by the customer after a short cycle of petroleum oil has been run.

Email author with any questions: dave@performanceoiltechnology.com

2. HYDRODYNAMIC AND BOUNDARY LUBRICATION

The film of oil between two moving surfaces such as a crankshaft to a bearing can be described in several phases: boundary lubrication, mixed lubrication, hydrodynamic lubrication and elasto-hydrodynamic lubrication. For purposes of this description the properties we are going to be most concerned with are **hydrodynamic lubrication and boundary lubrication.**

Hydrodynamic lubrication is the lubrication that is achieved by the movement of the oil. The rotation of the crankshaft forces the lubricant to move into the loaded zone of the bearing/crankshaft. As the oil is forced to move into this loaded zone, the pressure increases and it is this hydrodynamic pressure that supports the crankshaft load. As the load increases the oil film thickness is reduced while increasing the hydrodynamic pressure increases the oil film thickness. Hydrodynamic lubrication is present when two components (crankshaft/connecting rods and bearings) are moving at high RPM. The only property of a lubricant that is important in hydrodynamic lubrication is its viscosity. However, viscosity can vary due to the operating parameters of an engine such as pressure/load, temperature and shear forces.

Boundary lubrication exists whenever the oil film thickness becomes too small to provide a film separation of the surfaces. The oil film has become so thin that there is no hydrodynamic lubrication. This is where the properties of a motor oil, other than the viscosity are very important.

Boundary lubrication can occur when the oil viscosity is too low, the crankshaft speed is too low or the load on the bearing/crankshaft is too high. It can also occur if there is a partial loss of lubricant to the bearing.

Motor oils have to be formulated to provide adequate lubrication and protection during both hydrodynamic lubrication in which the viscosity is the prime consideration and also during boundary lubrication in which the presence of anti-wear and load carrying additives are required.

If the boundary lubrication properties of a motor oil are satisfactory, the oil will perform properly. However, the problem becomes how to engineer a particular oil such that it will maintain the required properties for the specific period of service it is specified for during which time it will be subjected to extreme heat, load, unburned fuel, soot, acid, oxides of nitrogen, water and wear metals and contaminants introduced into the engine from the engines air intake.

The next section will address the specifics of exactly what happens to a motor oil during use in an internal combustion engine and what properties are required such that the oil will provide adequate protection.

Email author with any questions: dave@performanceoiltechnology.com

3. CHEMICAL BREAKDOWN & DETERIORATION DURING USE

OXIDATION AND DEPOSITS

Oxidation is the most important form of chemical breakdown of a motor oil and its additives. The chemicals in a motor oil are continuously reacting with oxygen inside an engine. The effects of oxidation due to this reaction as well as the by-products of combustion produce very acidic compounds inside an engine. These acidic compounds cause corrosion of internal engine components, deposits, changes in oil viscosity, varnish, sludge and other insoluble oxidation products that can cause a performance and durability degradation of your engine over a period of time. The products of oxidation are less stable than the original base hydrocarbon molecular structure and as they continue to be attacked by these acidic compounds can produce varnish and sludge.

As an engine goes through multiple heating and cooling cycles this sludge can harden and cause other problems such as restricted passageways and decreased component tolerances. Varnish can cause such things as piston ring and valve sticking. The deposits can also affect heat transfer from pistons to cylinder and in extreme cases can cause seizure of the piston in the cylinder. Pistons also have oil return slots machined into them that can become plugged and result in increased oil consumption and additional deposits created on top of the deposits that are already there. Deposits also form on the tops of pistons which over a period of time can cause pre-ignition, increased fuel octane requirements, detonation/pinging and increased exhaust hydrocarbon emissions and an overall destructive effect on the engines internal parts. Deposits also form inside valve covers, timing gear covers, oil pump pickup screens, oil filters and oil passageways.

Part of the job of refining petroleum oil is to remove as many naturally occurring chemicals that can reduce the oxidation resistance of an oil. Oxidation resistance can then be improved by the addition of additives engineered into the oil, such as **anti-oxidants**. Anti-oxidants include several different chemicals with the most common one being ZDDP (Zinc Diethyl Dithiophosphate). Anti-oxidants also become depleted with use and when that happens the oil starts to oxidize rapidly. These and other oil additives will be discussed in more detail in section 4 of this book.

Refining an oil to reduce these naturally occurring chemicals that can lead to oxidation also tends to inhibit the capability of an oil to provide good boundary lubrication. Some of these chemicals that are refined out include aromatics, unsaturates and napthenes. Therefore, a petroleum motor oil that has been highly refined using modern techniques will have good oxidation resistance but poor boundary lubrication. Boundary lubrication can be improved by the use of engineered additives blended in by the oil manufacturer. This illustrates the case that refining a petroleum oil is a compromise. The chemicals that come out of the ground cannot be controlled and have to be refined out. The extent of refining is usually selected to give the proper balance to meet the specifications for a particular grade of lubricant, whether it be for high performance, severe duty, average use or anywhere in between.

THERMAL DEGRADATION

When a motor oil is heated beyond a certain temperature it will start to degrade, even if there is no oxygen present. This is called thermal degradation and causes the oil to change viscosity. The thermal stability of a motor oil cannot be improved by use of additives but it can be improved by refining out the same compounds that decrease the oxidation resistance. As temperatures increase, thermal degradation increases. In order for an oil to provide proper service and protection at high operating temperatures highly refined oils with plenty of anti-oxidants should be used. For average service less highly refined oils can be used. There is also a direct correlation between price of a particular oil and it's performance under temperature extremes. Less costly oils are generally refined less and have a lower capability to prevent/reduce thermal degradation. Petroleum oils have a much lower operating temperature range while premium quality synthetic motor oils have a very high operating temperature range and are much more resistant to thermal degradation.

CORROSION

A petroleum oil that is new or kept clean by proper filtration is generally non-corrosive and will provide good protection against corrosion caused by the atmosphere. However, inside an engine oil oxidation by-products will attack internal engine steel and bearing materials that are typically manufactured aluminum, copper, lead and tin (a lead-tin flashing is used for break-in purposes on the few engines that use aluminum rod and main bearings). Most gasoline and diesel engines use copper-lead main and connecting rod bearings.

Water present due to condensation caused by temperature and humidity changes or short stop and go driving where the engine never reaches the proper operating temperature, although still hotter than the ambient temperature, can also cause corrosion. The hotter the oil is when water is present the more severe the chemical reaction is and corrosion related damage could definitely occur. In addition, water present in an oil for an extended period of time can emulsify the oil and form a mixture which is much more corrosive than the two components alone and can then form sludge which may block oil filters or small passages. It is critical to operate en engine at normal operating temperature to prevent, as well as burn off any water that is present by an evaporation process. The most severe type of driving an oil can be subjected to (as well as an engines internal components) is short drives and intermittent operation in which the engine and oil never has time to reach normal operating temperatures for an extended period of time.

A quality motor oil will have a corrosion inhibitor added. Corrosion inhibitors also vary in terms of effectiveness, quality and quantity. Again, less costly oils may not protect against corrosion as well as more expensive motor oils that have a better corrosion additive package. Some common corrosion inhibitors include ZDDP (Zinc Diethyl Dithiophosphate), Calcium and Barium Sulphonates.

SHEARING

You probably have heard of the word "oil breakdown". Many people use this term to represent what they think is a motor oil that has "broken down" and is in need of changing, when in reality the actual process of "break down " is not properly understood. The correct word for this is **oil breakdown due to shear forces**. An internal combustion engine imparts high shear forces on a motor oil, which is sandwiched between two rotating or sliding forces under load and heat. The molecular structure is essentially torn apart by these mechanical shear forces. The component of the oil that is affected most by these shear forces is the viscosity improvers. These viscosity improvers allow the manufacturer of the oil to create multi-grade oils suitable for a wider temperature range of operation and are covered in detail in another section of this book. The end result of these shear forces is a decrease in the viscosity of the oil as well as a decrease in the viscosity index. Once a motor oil has sheared beyond a specific point it will not revert back to it's base structure when it cools down and the shear forces have ceased. Keep in mind also that I am referring to petroleum oils only. Synthetic motor oils are extremely resistant to the detrimental effects of shear forces.

Another way to explain this phenomenon is as follows: If you look at the molecular structure of a motor oil under a microscope you will see chains of molecules grouped together and linked together. The smaller molecular particles are attached to the larger ones. As an oil shears these smaller molecules break away and align in the chain. As engine heat and shear forces continue and increase these molecules break away from the base structure and in the process provide less and less resistance to wear. If this shearing and excessive continues over an extended period of time engine damage can occur. If shearing is only mild, then when the oil cools down the structure will revert back to its original structure and still be capable of providing proper engine protection. Multi-viscosity petroleum motor oils are more susceptible to shearing than straight weight petroleum motor oils. As previously mentioned synthetic oils are extremely shear resistant and will be covered in detail in Section 14 of this book

WHAT ABOUT ENGINES THAT "REQUIRE" A STRAIGHT WEIGHT OIL?

While we are on the subject of oil shearing I though it appropriate to discuss this topic. I get many calls asking why manufacturers of small engines such as used in lawn mowers, generators and even some larger diesel engines "require" either a SAE 30 or SAE 40 oil. The reason is that first and foremost, **they are referring to petroleum motor oil**. These types of engines operate under extreme RPM, load and heat and in the case of small engines are mainly air-cooled. Multi-viscosity petroleum oils are full of viscosity improvers (VI's). It is these viscosity improvers that are the weak link. As these agents are subjected to heat, load and high RPM the oil cannot reach its intended high temperature viscosity, which results in shearing. As this shearing continues the results can be loss of oil film strength, increased wear rates and temperatures and oil consumption issues. That is the reason straight weight **petroleum oils** are recommended for these types of applications. When a quality multi-viscosity synthetic oil, such as a

10W-30, 10W-40 or 15W-40 is used these concerns are non-existent. Synthetic oil is extremely shear resistant. The bottom line is that the manufacturers specifications are based on petroleum oils, yet your owner's manual is not going to explain that, so you in turn go out looking for the "required" straight weight petroleum oil. You would be much better off using synthetic oil in these types of applications. Synthetic oils will be covered in detail in later sections of this book.

CONTAMINATION

Motor oil contamination also causes deterioration of the oil. Some of the more common contaminant sources include dirt, sand and dust from the air, soot, unburned fuel in the oil, water from condensation of the combustion process, wear metal particulates that the oil filter cannot trap and hold, corrosion by-products and additive elements that have degraded. In addition dirt, sand and dust can continue to enter the engine and, in addition to creating more wear debris, combine with other contaminants and cause more damage than they would separately.

One of the many by-products of combustion and/or blowby is soot. Soot can be highly abrasive as well as cause filters to become filled and/or plugged in extreme cases. Another contaminant is acidic by-products of combustion, which can produce a highly corrosive mixture and cause corrosion and pitting of internal engine components and additional generation of wear debris. These same acidic solutions can also mix with water inside the engine and form an emulsion that can cause problems with oil filters and passageways.

Yet another source of contamination is fuel. A charge of fuel is rarely 100% burned during the combustion process. This unburned fuel can mix with the oil present in the cylinders. Fuel contamination can also be caused by worn sealing components such as excessive piston ring to cylinder clearances allowing unburned fuel to blowby the rings. When a motor oil is diluted with fuel the effect is that the viscosity is lowered. If this reaches extremes of contamination excessive wear and engine damage can take place. Operating an engine not sufficiently warmed up can also increase combustion blowby. It is much better to let your engine sufficiently warm up before driving away which can have a significant effect on preventing fuel blow by as well as producing a much more efficient combustion cycle.

The control of these sources of contamination both through proper air and oil filtration as well as oil additives will be covered in the following section.

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4. MOTOR OIL ADDITIVES BLENDED IN DURING THE MANUFACTURING PROCESS

After reading the previous section you may ask yourself how can a motor oil possibly survive with all the possible sources of contamination, wear and deposits. The answer lies in proper blending of additives during the manufacture of the oil as well as in proper air and oil filtration.

The additives we are referring to are not aftermarket oil additives. Aftermarket oil additives, regardless of their exaggerated claims, infomercials and testimonials are not required and in many cases are detrimental to the proper function of a motor oil. These has been no documented laboratory or field tests that I am aware of performed by auto and equipment manufacturers that support the use of any type of aftermarket oil additives. In fact, the Federal Trade Commission (FTC) has recently charged many of these aftermarket additive marketers and/or manufacturers with false and deceptive advertising. This topic will be covered in detail section 5 of this book

The additives that I am referring to that an oil company blends in are specifically designed and engineered to impart specific properties to a finished motor oil formulation. These specific additives cause a motor oils life cycle to be extended and/or reduce the rate at which undesirable changes take place while others improve properties already present in the base oil. Before I cover the additives I will provide some background information on where oil actually comes from and how it is produced.

"MOTOR OIL REFINING"

I often recall the story that a friend in the crude oil refining business told me. Being in the oil business for most of his career he would regularly run into people that would ask which of his companies oil wells pumped 5W-30, which wells pumped 10W-30 and which oils pumped diesel oils and so on. I get a good laugh out of it every time I think about it. The fact is the large oil companies do not exist to produce motor oils exclusively.

Motor oils are made from the more viscous portion of the crude oil that remains after removal by distillation of the gas and oil lighter fractions. Crude oil rarely ever is used without processing except in some specific cases for fuel to operate power plants or for certain asphalts. In most cases it is first separated into different fractions that require very detailed additional processing in order to begin to develop lubricating oils with specific properties, such as a 5W-30, 10W-30 or a 15W-40 diesel motor oil. The first and foremost products produced from drilling are in order to refine the crude oil to produce gasoline and diesel fuels, kerosene and home heating oils.

There are also several different types of crude oil depending on what part of the world it comes from. Crude oils can come in light grades that yield primarily gasoline to heavy black crude oil. The hydrogen carbon atom structures of the crude oils vary a great deal as do the impurities, such as sulfur or wax. Some crude oil is only suitable for manufacturing gasoline, diesel and fuel oil and by-products, while others are preferred for manufacturing lubricating oils. The three basic types of crude oil stocks are paraffinic, napthenic and asphaltic. Lubricating oils are generally produced from paraffinic and napthenic stocks. Different types of crude stocks allow refiners to select those that, when fully refined, will provide base stocks that meet their specific needs. Keep in mind that companies use different quality base stocks to manufacture their finished products. Some companies may choose to use a very high quality base stock, in addition to carefully selected and blended additives, while others may choose a lower quality, and thus less costly, base stock combined with more chemical additives to yield a similar product, however the quality and performance can vary significantly, even though both products may meet the same specifications. Also keep in mind that although both products may meet the same specifications, one has no way of knowing at which end of the specification range the product fall into and how that product meets those specifications on a continuing basis. The old saying, you get what you pay for, holds true for many petroleum products (both lubricating oils and gasoline and diesel fuel) just as it does for most other products.

The first step in processing crude oil is to remove inorganic salts and water, which can form acids during processing and damage refinery equipment. After the crude is de-salted it is pumped through a complex series of heated pipes in order to vaporize and enter what is called a fractioning tower where groups of hydrocarbons are separated according to their boiling ranges. This occurs because the fractioning tower is at different temperatures from the top to the bottom, with the bottom being the hottest. Light hydrocarbons such as raw gasoline, called Naptha, are vaporized to the top of the tower and then condensed to form liquid again by cooling. The lower parts of the tower are much hotter and trap the heavier hydrocarbons such as diesel fuel, kerosene, heating fuel oil and other heavy oils, which are subsequently pumped to different fractioning towers for further processing. The products remaining in the very bottom of the fractioning tower are typically used for making asphalt for roads (f).

So, as you can deduce from this very simplified explanation of the crude oil refining process, motor oil is not always the prime objective. In fact, it is a by-product remaining after the valuable gasoline and diesel fuels and kerosene and home heating oils are processed. Once the crude oil is separated and further refined to a point where a specific type of motor oil can be produced, many additional additives are required to be blended in to produce a finished product ready to bottle and distribute. There are also many different refining processes and it is not my intention to cover these processes here, only to provide you with a very basic understanding of how petroleum motor oil is produced.

POUR POINT DEPRESSANTS

Petroleum motor oils have waxes and paraffin that come out of the ground with the crude oil. It is very expensive to refine out these waxes and paraffin's. There is a process to do this, called hydroprocessing, which I will discuss in later sections of this book, however average quality oils are not hydroprocessed. Instead, pour point depressants are added. These additives are required in order to obtain low pour points. They do not prevent the formation of wax crystals as temperatures decline, but rather lower the point at which wax crystals form and also restrict the growth of wax crystals.

VISCOSITY INDEX IMPROVERS

A motor oil must not be too viscous (thick) at low temperatures in order to promote easy cold weather starting but at the same time it must not be too fluid (thin) at higher operating temperatures in order to prevent excessive wear and prevent excessive oil consumption. Viscosity Index Improvers (VI's) are blended in a motor oil in order to impart specific performance characteristics to the oil under these operating extremes. For example, this allows for a motor oil to act like a 10-weight when it is cold but when it warms up to operating temperatures it acts as a 30-weight oil.

The determination of how well a particular motor oil meets these criteria is called the Viscosity Index (VI). VI is strictly an empirical number and indicates the effect of change in temperature on viscosity. The lower the VI, the larger a change in viscosity with temperature changes. There is a specific ASTM (American Society of Testing Materials) Test D-2270 that is used to determine the VI of a motor oil.

The problem that can occur in petroleum based motor oils with VI's is that under heat, load and shear forces the molecules of the VI tend to change shape from a round shaped molecular structure to a straightened, or aligned, molecular structure. When this occurs the VI's are subject to degradation due to shear forces created inside the engine, which can cause a temporary loss of the oils specified viscosity. Under shear loads the molecules in the VI's align themselves in the direction of the shear stresses so there is less resistance to flow. As the oil cools and the shear forces are no longer present the VI's return to their original molecular configuration and the original viscosity is returned to the oil. **Where serious problems can occur are under extreme heat and shear loads where the molecular structure of the VI's are permanently destroyed and will not return to their original configuration when the oil cools and shear stresses are no longer present.** This is the prime reason that, as discussed previously, small engine manufacturers and some diesel engine manufacturers specify a straight weight petroleum oil with no VI's.

In general, the greater the spread in viscosity of an oil, the more susceptible the oil is to shear under load and heat due to the greater quantity of VI Improvers required to achieve the spread, such as in a 5W-50 motor oil, for example. Please keep in mind that these issues with VI's are in relation to petroleum motor only. Synthetic multi-viscosity motor oil is extremely shear resistant. I will cover synthetic motor oils in detail in section 14 of this book.

DETERGENTS AND DISPERSANTS

With the development of heavy-duty diesel engines plain petroleum oil could not meet the requirements of these engines. Deposits left by the oil caused piston ring sticking and rapid wear very early on as well as blocked oil flow passages. Soon after this began occurring oil manufacturers started to use a soap blend in the oil, which kept internal components clean by significantly reducing the formation of deposits. Over the years much more advanced chemicals were developed and used as detergents and dispersants.

The use of these detergents does not clean an engine but rather serve to delay the formation of deposits and reduce the rate at which they accumulate. They do this by neutralizing the acidic by-products of combustion. One of the main reasons why people were told to change their oil frequently is to remove the contaminants from the oil before the oils capacity to neutralize and hold them is exceeded.

Dispersants are chemicals blended into the oil that suspend materials that can cause sludge, varnish and lacquer resulting from oil oxidation to form.

The measure of an oils ability to neutralize these acidic by-products of combustion is called the Total Base Number (TBN). It is a measure of an oils reserve alkalinity. The higher the TBN, the better an oils ability to neutralize acids. A TBN of 7 is typical for an average quality gasoline engine petroleum oil. Premium quality extended drain interval synthetic oils typically have a TBN of 11-12. Petroleum and synthetic diesel oils have higher TBN values due to the increased acidic by-products of combustion created by the diesel fuel combustion process. These values can range from 8-11 up to 12-14 for premium quality diesel oils.

ANTI-FOAM AGENTS

Most motor oil has some type of anti-foam additive blended in. This is due to the fact that petroleum oils are subjected to extreme agitation primarily due the high RPM of a rotating crankshaft and also the movement and circulation of oil in valvetrain components. The action created by the oil pump and the effect of blow-by gasses mixing with the oil also causes foaming. A motor oil that foams excessively cannot perform the job of properly lubricating an engine under severe operating conditions, or even in average operating conditions. When air bubbles form in the foam, the anti-foam additives will attach themselves to the air bubbles in the foam and cause the foam to weaken which in turn causes other foam bubbles attached to each other to collapse. The anti-foam additive essentially breaks down the foam when the oil film surrounding the air bubbles is ruptured. There is an ASTM D-892 test that measures a motor oils ability to resist foaming.

RUST AND CORROSION INHIBITORS

Rust inhibitors are special compounds blended into a motor oil that, in addition to the motor oil itself, attach themselves to internal components and prevent the formation of rust by forming a barrier that prevents water from contacting the metal surface. This additive is extremely tenacious and once it attaches itself to the component it will remain there in order to do its job, especially during engine shutdown. This additive is sacrificial in nature and does deplete with time in service.

The **only** way to determine if these additives are still present in sufficient quantity to effectively prevent rust is to perform oil analysis testing or use the specific brand/type of motor oil according to the oil manufacturers specified change intervals. There are a two brands of premium quality synthetic motor oils on the market that are designed and engineered for extended drain intervals of 25,000 miles/1-year and one brand engineered for up to 35,000 miles/1-year in which, when used according to the oil manufacturers recommendations, will provide exceptional rust and corrosion prevention for the entire mileage/time interval. In order to use **any** motor oil past the oil manufacturers recommendations oil analysis testing must be used. Oil analysis testing will be covered in section 20 of this book.

Corrosion inhibitors are blended into motor oil and serve the functions of preventing corrosion of internal engine bearings made from a mix of copper, lead, aluminum and tine. The acids formed in the oil are extremely corrosive and are a result of the combustion process of gasoline and diesels fuels as well as the additives that were blended in with the fuel itself. These by-products of combustion are deposited on the cylinder wall portions that are exposed to the combustion flame front above the top of the piston and then carried into other components by the oil. Direct blow-by is also a cause of acidic contaminants in the oil. The amount of blow-by in a particular engine is dependent on many factors, with the primary one being the effectiveness of the seal between the piston rings to the cylinder. The acids formed as a result of this will corrode internal parts such as bearings, pistons/cylinders/rings, rockers, camshafts, valves, timing gear teeth and other ferrous and non-ferrous components within the engine.

There are two primary types of corrosion inhibitor chemicals and functions: one is for the additive in the oil to chemically bond to the internal parts and provide a sacrificial barrier and the other is to actually neutralize the acids so that the corrosive potency is reduced to a level where it cannot do any internal damage. This additive depletes with time in service.

Common additives for these purposes include Zinc, Phosphorus and Zinc Diethyl Dithiophosphate (ZDDP), Calcium and Barium. Barium Sulfonates and Calcium Phenates are common chemicals that are engineered with a high amount of the alkali metals Barium and Calcium in order to provide adequate neutralizatization capability specifically due to the alkalinity of these metals. Sulfur content in both gasoline and especially diesel fuel are one of the primary causes of acids in a motor oil.

As a side note relative to rust and corrosion protection: I currently hold two U.S. Patents for corrosion prevention between two securely bolted together metal parts that must still have metal-to-metal contact and also for preventing corrosion on exposed brake rotors. The specific application of one of these patents will be discussed in the special bonus section of this book and will be beneficial knowledge to any automotive enthusiast and may help you to solve current problems when combined with my other service procedures that have been proven over many years and millions of vehicles to prevent one of the most common automotive braking problems from occurring.

OXIDATION INHIBITORS

Oxidation is the result of oxygen mixing with oil at engine operating temperatures. It is not so much the amount of oxygen absorbed by the oil that is important, but the amount of oxidation products formed. Oxidation causes an increase in oil viscosity as well as the formation of acids, resins, lacquers and varnish on internal parts, and especially on pistons and piston rings. More severe oxidation occurs as engine operating temperatures increase.

The effect of varnish, resins and lacquers on pistons and piston rings can cause a decrease in the amount of heat transfer between the piston and cylinder as well as stuck piston rings, leading to severe engine damage over a period of time. If the temperatures continue to increase to extremes then these deposits will continue to oxidize into very hard carbon type materials. When this hard carbon material meets with combustion residues and water, sludge is formed. Sludge can do further damage such as plug and block critical oil passageways and oil pump pick-up screens.

In order to decrease the effects of oxidation, oxidation inhibitors are used which disrupt the chemical reaction that is responsible for the formation of the oxidation as well as chemicals that actually decompose the oxidation products already formed. The lacquers, resins and varnish are not only formed at high temperatures by the oil, but also a low to medium operating temperatures by the fuel combustion process. There are numerous very complex chemicals that are used as oxidation inhibitors and it is not my intention to go into the detail of what these chemicals actually are in this book.

ANTI-WEAR ADDITIVES

Anti-wear additives are mainly used in order to reduce the effects of engine operating conditions when a full hydrodynamic oil film cannot be maintained which, as discussed previously, are known as boundary lubrication conditions of slow speed and low load. These anti-wear additives primarily act as friction reducers that prevent metal-to-metal contact. Zinc and phosphorus are common anti-wear additives.

Under high engine speeds, high loads and operating temperatures, even though hydrodynamic lubrication is present, extreme pressure (EP) additives are sometimes used by certain oil manufacturers to reduce friction further and control wear. EP additives are also used extensively in gear lubes. The chemicals used as EP additives include either sulfur, phosphorus, chlorine, molybdenum disulphide or a blend of these additives depending on the specific application. Not all motor oil manufacturers use EP additives as they can also have a detrimental effect on other engine operating parameters and can also be highly corrosive to certain metallurgical bearing compositions and can also be incompatible with alkaline detergent additives.

Email author with any questions: dave@performanceoiltechnology.com

5. COMPLEX CHEMICAL ADDITIVES VS. AFTERMARKET ADDITIVES

Now that you have learned some of the basic chemical additives engineered into a motor oil by highly skilled chemists, scientists and lubrication engineers I ask you to think about this question: how can it be that an aftermarket additive company can come out with an off-the-shelf additive that they claim you can pour into any motor oil and it will perform all kinds of phenomenal things the motor oil as engineered by the oil manufacturer seemingly cannot?

I have not seen an aftermarket additive company provide independent ASTM, SAE and ISO Certified Laboratory Test Data substantiating their claims. First of all, the chemistry of a particular motor oils is proprietary and it is not plausible that an aftermarket additive company can engineer one additive to enhance the performance of any motor oil without knowing the exact chemical composition of that particular motor oil. Different base stock motor oils and manufacturer additive package formulations each respond differently to aftermarket oil additives.

Secondarily, a base oil formulation, which is inferior, cannot be converted into a top quality motor oil simply by pouring in an aftermarket oil additive. What works in one motor oil may have totally different effects in another brand and/or type of motor oil.

As an engineer with an entire career of experience in the auto industry I have not seen any documented test data from an OEM auto manufacturers R&D labs that can substantiate the use of aftermarket oil additives. For example:

- In its owner's manual, *Ford Motor Co.* recommends against the use of aftermarket lubricant additives (ALAs) for engines, transmissions, transaxles, etc. For example, the engine oil section in the 2003 Ranger pickup's manual states twice, for emphasis, on the same page, "Do not use supplemental engine oil additives, cleaners or other engine treatments. They are unnecessary and could lead to engine damage that is not covered by Ford warranty."

- "Don't add anything to you oil." – *1998 Buick Regal owner's manual*

- "Do not add any material (other than leak detection dyes) to engine oil. Engine oil is an engineered product and its performance may be impaired by supplemental additives." – *2003 DaimlerChrysler owner's manual*

- "Using supplemental additives is generally unnecessary **and can even be harmful** (emphasis added). One should never use an additive to fix a mechanical problem." – *Detroit Diesel bulletin several years ago*

- "ExxonMobil does not recommend (additive supplements and/or engine treatments)." – *Mobil 1 website*

It is my opinion as an Automotive Engineer that aftermarket oil additives are unnecessary and could potentially be detrimental to the chemistry of a motor oil. Without going into extensive detail here's a general summary of what you need to know about aftermarket oil additives: There are basically two types of additives used, either Teflon based with PTFE or Chlorinated based with some type of carrier, usually a paraffin based carrier or other mineral oil. Some have extremely large amounts of moly, zinc or phosphorus, all extreme pressure agents which can potentially be detrimental to a motor oils proper function.

Teflon does absolutely nothing inside your engine. Teflon must be heated up to about 800 deg. F to get it to stick to anything for friction reducing purposes, just like the Teflon on a frying pan, yet in an engine suspended microscopic colloidal Teflon particles can potentially gradually attach to the oil pick-up screen and reduce oil flow to critical components as well as reducing the oil flow in other critical internal engine passages by attaching themselves to the passageway walls. In addition, as the oil filter filters out some of the Teflon particles, the filter flow rate can potentially be reduced which in turn may eventually become restricted and could potentially default to the by-pass mode of operation, which means unfiltered oil will then flow through the engine.

If you ever get bleach on your fingers you will notice how slippery it is. Add enough Chlorinated components to a mineral based carrier and mix it with some type of teflon, moly, zinc or phosphorus and you can reduce friction, except for one concern: chlorinated additives mixed with oil and subjected to heat forms hydrochloric acid. Hydrochloric acid is detrimental to internal engine components.

The bottom line is: When using a properly formulated motor oil you do not need any aftermarket additives and additionally, the additives you may put in can potentially be incompatible with the additives the oil company carefully blended in. The major oil and OEM additive companies (that supply raw materials and chemicals to the oil companies) are some of the wealthiest and most powerful companies in the world, and they certainly can and do hire highly skilled chemists that know how to properly formulate a motor oil **(this is not to say they make a premium quality motor oil; just that they know how to properly formulate one to perform the functions it was designed to do and meet the required specifications).**

Many aftermarket oil additive companies make claims that are not accompanied by Certified Test Data. I have yet to see an aftermarket additive company provide independent ASTM, SAE and ISO Certified Laboratory Test Data substantiating their claims.

What if they have a Test to Show How their Additive Works

At a recent trade show we were at an aftermarket oil additive company was there with a machine that demonstrated how their additive reduced friction. It was a motor with rotating solid steel disc secured to the motor shaft and a torque meter with a flat piece of steel mounted on the torque arm. They put every type of oil on the market, one by one, on the machine & pressed hard on the torque meter and at about 20-40 lb-ft torque the torque arm would stall the motor....that is until they cleaned it off and tried their (chlorinated) aftermarket oil additive on the bearing & ran the test.

People were amazed as the meter peaked out at 140 lb-ft. torque and still didn't stall the motor. We knew what was happening but many unsuspecting consumers were impressed up and standing in line to buy the additive. The next day we showed up with some Head & Shoulders Shampoo disguised in an oil bottle & had the aftermarket oil additive people try it on their test machine. The operator was amazed as the motor just barely stalled at 140 lb-ft. The operator says that's pretty good stuff, what is it? We said "Head & Shoulders Brand Shampoo. He was quite embarrassed to say the least. Head & Shoulders Brand Shampoo has **high levels of high potency ZINC** in it that attaches itself to ferrous metals. Coke soft drink can do the same thing. ZINC reduces friction and provides anti-wear protection and is present in most motor oils at a much reduced level. Now, would you put Head & Shoulders Brand Shampoo in your engine?

Additionally, the test machine was measuring **Extreme Pressure. Motor oils do not have Extreme Pressure (EP) additives** blended in like gear lubes do nor do they need extreme pressure additives. A gear lube would not stall the motor as easily because gear lubes have high levels of Extreme Pressure additives blended in.

As a side note, I know of two auto-parts stores within a half-mile of each other. One is a well-known family owned high quality performance type store. The owners of this store use the products they sell and also design and build racing and performance cars and have a full machine shop. They will not sell any type or brand of aftermarket oil additive.

Yet, just down the road the owner of a large discount chain walked down the aisle with myself and a business associate where he has at least a dozen different aftermarket oil additives on display and waves his hand as he walks by these additives and says " this stuff is ineffective, but we sell a lot of it".

In fact, "in the case of oil additives, there is a considerable volume of evidence against their effectiveness. This evidence comes from well-known and identifiable expert sources, including independent research laboratories, state universities major engine manufacturers, and even NASA" (c).

Additionally, as an engineer at one of the major automotive engineering and manufacturing companies, I have the opportunity to work with some of the worlds most skilled and knowledgeable engineers from one of the most successful and well-known national race teams in history. None, and I mean absolutely none, of their cars use an aftermarket oil additive. They only use synthetic oil, and not just any synthetic oil but the absolute best synthetic oil there is.

In summary, I do not recommend the use of any aftermarket oil additives, regardless of how convincing their claims are. Instead, I recommend that you take the time to research the many different brands of premium quality synthetic motor oil on the market and select the product that proves to offer the best overall performance, protection and value. Take a look at the test and performance data and make an educated decision based on independent ASTM and ISO Certified laboratory and field test data.

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6. LUBRICANT TESTING AND FUNCTIONAL TESTS

There are many chemical, physical and performance tests that exist. I will cover the most commonly used ASTM tests in this section. The ASTM is the American Society for Testing and Materials. It is a scientific, engineering and technical organization that develops standards on the performance parameters and physical characteristics of specific materials used in engineering and manufacturing.

POUR POINT (ASTM D-92)

The pour point of an oil is the lowest temperature that the oil will flow. Most petroleum based oils have waxes and paraffin that solidify at cold temperatures. Oils with more waxes and paraffins will have a higher pour point while highly refined oils and synthetic oils will have significantly lower pour points. The viscosity of an oil also affects the pour point. An oil with a high viscosity, even though it may be wax and paraffin free, is still limited in it's pour point due to the higher viscosity.

Pour point is a very important parameter especially for people that live in cold climates. The oil must be able to flow into the oil pump and be pumped to various parts of the engine at the lowest anticipated temperatures. The pour point should not be used as the only selection criteria for cold weather operation. The fact that a motor oil has a specific pour point does not necessarily mean that it will properly pump through the engine at the lowest pour point temperature that the oil is rated for. A combination of low pour point combined with the frictional effect of the oil being pumped through a vane or rotor type oil pump and heat from the engine gradually warming the oil will cause the oil to flow to increase so that it properly flows to the necessary engine components.

Additionally, the pour point of a motor oil can change with time in service as the pour point depressant additives in petroleum based oils are consumed. Synthetic motor oils do not use these pour point depressants and thus have much more consistent pour points after time in service.

FLASH AND FIRE POINT (ASTM D-92)

The flash point is the lowest temperature that a flame will cause the vapors of a lubricant to ignite. The fire point is the lowest temperature that a particular oil will sustain burning for five seconds. The test sample is heated and a flame is brought near its surface. Flash points are the most commonly used flammability tests and are typically used for safety of shipping, handling and storage of lubricants. Generally, in specific high temperature engine operation an oil with a low flash point would indicate higher volatility and thus may result in higher rates of oil consumption. Flash and fire points can be drastically reduced when fuel contamination is present in a motor oil.

KINEMATIC VISCOSITY (ASTM D-445)

Kinematic viscosity is a measurement of the time taken for a known volume of oil to flow under gravity through a calibrated glass capillary viscometer. Kinematic viscosity is measured at 40 deg. C. (104 deg. F) and 100 deg. C. (212 deg. F.) in order to have standard reporting temperatures. It is essentially the ratio of the viscosity to the density of the oil being tested.

Kinematic viscosity is typically measured in centistokes (cSt). Centistokes can be thought of as the result of dividing the dynamic viscosity of an oil by its density, both measured at the same temperature. Dynamic viscosity (measured in centipoise or in Pascal seconds) is the force required to overcome fluid friction in an oil film of a known dimensions and thickness. I will not go into detailed engineering descriptions and calculations of dynamic viscosity as it gets into complex engineering calculations. I will explain kinematic viscosity in relation to practical applications in the selection of a multi viscosity 30-weight motor oil in section 23 of this book.

VISCOSITY INDEX (ASTM D-2270)

The viscosity index is used to determine how much a particular motor oils viscosity changes with temperature. It is a method of applying a number to this rate of change based on a comparison with two arbitrary selected oils (published in tables by the ASTM at a given temperature typically 40 deg. C and 100 deg. C) that have significant variations in viscosity index. A high viscosity index would indicate a low rate of change of viscosity with temperature while a low viscosity index would indicate a high rate of change of viscosity with temperature. High viscosity index motor oils protect better in engines that operate with temperature variations, which includes all auto and light truck engines. Motor oils that have a large amount of viscosity index improvers tend to degrade more rapidly than motor oils that have less viscosity improvers. Synthetic oils, by their inherent nature, have significantly less viscosity improvers than an equivalent viscosity in a petroleum oil and thus tend to have high viscosity index values and are more stable.

HIGH TEMPERATURE/HIGH SHEAR VISCOSITY (ASTM D-4683)

This is a severe service test that measures the viscosity under high temperatures and high shear rates and is measured in units of centipoise. Lubricants with high values in this test will maintain their viscosity in high engine operating temperatures and when exposed to high load/high shear conditions.

NOACK VOLATILITY (ASTM D-5800)

This test is used to determine the evaporative losses of motor oil at high temperatures. Motor oils that have high evaporative losses will have higher rates of oil consumption. In addition, a motor oil that has higher evaporative losses in high temperature operation will have increased lacquer and varnish deposits as well as other negative changes in the particular oils chemical properties. A lower NOACK volatility rating indicates a motor oil that will have less evaporative losses and thus less oil consumption and increased engine protection and resistance to varnish, lacquer and sludge formation in critical engine areas such as pistons, cylinders and valvetrain components.

FOUR BALL WEAR TEST (ASTM D-4172B)

This is one of the most widely known and used test machines for measuring the wear preventative characteristics of lubricating oil. The machine consists of three fixed steel balls and one rotating steel ball. The machine can be set to different speeds, loads and temperatures. The balls are set into a bath of the particular oil being tested and the test is run typically for one hour at a specific load and RPM. At completion of the test the average wear scars on the three fixed balls are measured and reported.

Although this test does not simulate any bearing geometry internal to an engine, it is extremely useful in comparing the wear protection properties of various lubricants. Since the only variable in the test is the particular brand of oil, it provides and accurate comparison as to how well a lubricant will prevent wear inside an engine when compared to another competitive brand of oil of the same viscosity. In other words, it is an “apples to apples” test comparison. The smaller the wear scar the better the protection.

There is only one manufacturer that I am aware of that prominently displays and advertises how their oils perform in this test. This particular manufacturer (AMSOIL INC.) shows independent laboratory wear scar test results of their oil on every specification sheet and on the bottles of two of their high performance oils. I have yet to see another manufacturer that does well enough in these tests to display the results. I have contacted many other oil manufacturers and am told that this specification is not one that they advertise or disclose to the general public.

COLD CRANKING SIMULATOR APPARENT VISCOSITY (ASTM- D-2602):

Viscosities that are reported using the kinematic viscosity glass capillary test method do not adequately represent how a motor oils performs under cold cranking conditions. Therefore the Cold Cranking Simulator (CCS) test was developed in order to predict the cold cranking properties of oils used in automotive and truck crankcases. A 5 ml sample of oil is placed in the shear zone of the CCS test machine at room temperature. The shear zone consists of a rotor and stator. Coolant then begins to flow in order to drop the temperature of the oil. After three minutes the engine is run for one minute before the machines rotor speed is read. The CCS viscosity is determined in centipoises (cP) by referencing the speed readings obtained with a special calibration curve determined by standard reference oils. The resultant viscosity is called the apparent viscosity at low temperature. This test is extremely useful in predicting engine-cranking viscosities at specified low temperatures and how easily an engine will start in cold temperatures.

BORDERLINE PUMPING TEMPERATURE (ASTM D-3829)

The borderline pumping temperature is the lowest temperature at which a particular motor oil can be continuously and adequately supplied to the critical components of an internal combustion engine. In order to start an engine in cold temperatures certain minimum cranking speeds are required. If a motor oil exists with a viscosity that is so high that the engine is not capable of turning over fast enough it will not start. This is the primary reason oil and automotive manufacturers specify specific oil grades in specific ambient temperatures and batteries with adequate Cold Cranking Amperage (CCA).

In general, gasoline engines do not require as high of cranking speeds as diesel engines. The colder it gets outside, the higher cranking speeds are required of diesel engines. Diesel engines operate on the principle of adequate compression temperature sufficient to start the combustion process, which in turn depends on the ambient temperature and the cranking speed. This is why diesel engines use higher capacity, higher amperage dual batteries and heated intake air or heated crankcases and fuel tanks. Synthetic motor oils drastically improve the startability of both gasoline and diesel engines at low temperatures.

Recently I had a situation where a company I was consulting on their equipment was having cold starting problems with their heavy diesel logging and excavating equipment in the extreme cold winter temperatures of northern Michigan. The equipment was left outside away from any source of electricity so that block heaters could not be used. Often, before starting the equipment special propane powered heaters had to be aimed at the oil pan and engine block in order to sufficiently warm the engine and allow it to turn over at a high enough RPM to start the combustion process. After I recommended that they change to synthetic diesel oil the company no longer had starting problems. The oil I recommended has a pour point of minus 44 deg. F and CCS viscosity of 2120 at minus 5 deg. F. Synthetic oils do not have the waxes and paraffins that petroleum oils do and have drastically improved cold weather pumping and flow characteristics.

TOTAL BASE NUMBER (ASTM D-2896)

The Total Base Number (TBN) is a measure of the reserve alkalinity of a motor oil and how well the oil can neutralize harmful acidic by-products of combustion. The detergent/dispersant additive package is critical in determining how effective the motor oil is in neutralizing these acids. TBN depletes with time in service. Higher TBN oils are more effective at neutralizing acids for longer periods of time. In engine lubrication systems that use by-special pass filtration systems and do not change oil, TBN is monitored through oil analysis testing and also maintained by replenishing oil added during filter changes and topping off the oil.

A more specific explanation of TBN and TAN is as follows and is repeated as specified by Exxon Mobil. It is very important that you understand TBN: TBN is the quantity of acid, expressed in terms of the equivalent number of milligrams of potassium hydroxide, that is required to neutralize all basic constituents present on one gram of oil. This test is normally used with oils that contain alkaline, acid-neutralizing, additives. The rate of consumption of these additives (TBN depletion) is an indication of the projected serviceable life of the oil. With used oils, it indicates how much acid-neutralizing additive remains in the oil. Typical oils of this nature include diesel engine oils for internal combustion engines that use fuels containing acid-producing constituents such as sulfur or chlorine. As long as any significant amount of TBN remains in the oil, there should not be any strong acids present. However, the nature of high alkaline and metallic antioxidant additives sometimes allow for both TBN and TAN values to be obtained on the same sample. This occurs for both new and used oil (z).

TOTAL ACID NUMBER (ASTM D-664)

The Total Acid Number (TAN) of an oil is the weight in milligrams of potassium hydroxide required to neutralize one gram of oil and is a measure of all the materials in an oil that will react with the potassium hydroxide under specified test conditions. The usual major components of such materials are organic acids, soaps of heavy metals, intermediate and advanced oxidation products organic nitrates, nitro compounds and other compounds that may be present as additives. It is worth mentioning that new and used oil can exhibit both TAN and TBN values.

Organic acids may form as a result of progressive oxidation of the oil, and the heavy metal soaps result from reaction of these acids with metals. Mineral acids (i.e., strong inorganic acids), if present in an oil sample, are neutralized by potassium hydroxide and would, therefore, affect the TAN determination. However, such acids are seldom present except in internal combustion engines using high sulfur fuels or in cases of contamination. Since a variety of degradation products contribute to the TAN value, and since the organic acids present vary widely in corrosive properties, the test cannot be used to predict the corrosiveness of an oil under service conditions (z).

FOAM TESTS (ASTM D-892)

In this first phase of the foam measurement test air is blown through a sample of oil that is maintained at a specific temperature for a specific period of time. When the air supply is shut off the foam volume is measured. This is called the foaming tendency. In the second phase of the test, the foam is allowed to dissipate for ten minutes and then the volume of foam is measured and reported as the foam stability. The foam tendency and foam stability can change with time in service. New oils will have lower tendency to foam and lower foam stability values while oils that are contaminated can have increased values. The additive package in a particular oil is critical in the oils ability to reduce/eliminate foam both when the oil is new and after extended time in service. Certain manufacturers oils have highly effective anti-foaming additive packages and should be considered in applications where foaming is of critical importance.

Note that all oils will foam to a certain extent when agitated, however excessive foaming can lead to problems such as starvation at the oil pump inlet, or foam being drawn into the oil pump inlet with the oil. Foam is also detrimental to hydraulic valve lifter operation and the degree of oil film protection afforded by the oil. Certain motor oils, such as motor oils intended specifically for small high RPM engines typically have a special defoamant blended in the oil formulation. It is also important to note that excessively overfilling an engine crankcase can cause oil foaming, even with defoamants.

Email author with any questions: dave@performanceoiltechnology.com

7. OIL COLOR , LUBRICATION ABILITY AND CONTAMINATION LEVEL

It is a common misconception that an oil's color is an indication of how "dirty" it is. This is not true. It is often a common tactic used at quick lubes and service centers; the technician pulls the dipstick and wipes it on a white shop cloth and shows the customer how "black and dirty" it is. Any oil will turn black after a short period of use. Some oils may stay "clean" looking longer than others, but eventually they all will turn black. This is perfectly normal.

When someone tells me how "clean" their oil is because they have pulled the dipstick and it looks clean I always tell them that it will eventually turn black. They also tell me when they pull the dipstick and it has becomes black and "dirty" it will require changing. That's about the time I will pull my dipstick in one of my trucks and show them how black and "dirty" the oil is. I will then produce my latest oil analysis test report that provides laboratory chemical and spectrographic test data confirming that the oil perfectly suitable for continued service.

In general, the color of an oil does not have any bearing on its lubrication ability or whether or not the oil is suitable for continued use*. Most oil and especially diesel engine oil will turn black in the first few hours of operation due to contaminates generated by the combustion process and soot particles. It is the job of the filtration system to filter out the larger sized soot particles that can cause engine wear and the additive package of the oil to neutralize and hold in suspension the soot particles that are too small for the filter to trap and hold.

* Under certain conditions such fuel dilution, water contamination or glycol contamination, for example, the color can provide insight that something is mechanically wrong and in need of repair and/or additional analysis, however under normal operating conditions without mechanical problems present the black color which is commonly referred to as "dirty oil" in the vehicle servicing industry does not have any bearing on its lubrication ability.

The **only** way to accurately determine an oils lubricating value or contamination level is through (spectrographic) oil analysis. Oil analysis is common practice used regularly in commercial, industrial and fleet operations and can also be used for passenger cars, light trucks or any other application.

The useful life of an engine oil is dependent on several factors such as the quality of the oil, additive package blended in the oil and the TBN level of the oil (the ability of an oil to neutralize acidic by-products of combustion), type of fuel, equipment condition, type and operating environment of the equipment and the type of filtration.

The filtration system and the oil are vital tools for preserving engine life. A highly efficient oil filter is essential to protect an engine by removing both liquid abrasive contaminants held in suspension by the oil. It must be stated and understood with critical importance that there are wide variances in the quality of motor oils. Certain lower quality oils do not have quality base stock oils and additive packages to support long drain intervals while other higher quality oils can have significantly longer drain intervals. There are two oil manufacturers that I am aware of that make a premium quality synthetic motor oil that has standard recommended drain interval of 25,000 miles/1-year and one oil manufacturer has a 35,000 mile/1-year premium quality severe service synthetic oil with standard filtration or no oil changes with by-pass filtration and oil analysis monitoring. The subject of extended drain intervals and synthetics will be discussed in later sections.

Also keep in mind that the micron rating of an engine oil filter means absolutely nothing unless the efficiency (particle capture percentage) of the filter is stated also. If a filter is stated to be a "10 micron filter" but the efficiency graph shows it only traps 5% of the 10 micron particles then it isn't doing much good at filtering out 10 micron particles. Oil filtration and wear particles will be discussed in detail in section 17.

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8. ENGINE OIL SAE VISCOSITY CLASSIFICATION & MANUFACTURERS "REQUIREMENTS"

The SAE is the Society of Automotive Engineers. The SAE classifies motor oils according to certain viscosities and **very general** temperature ranges at which they can be used. Automobile and equipment manufacturers also specify which oil should be used for a particular ambient temperature operation. It is important to note that the viscosity and temperature range values listed by automobile and equipment manufacturers are almost always meant for **petroleum oil.** The same viscosity oil in a premium quality synthetic will have drastically lower cold temperature flow and operation properties as well as drastically higher high temperature operational properties. This is very important to remember this when determining which oil to use in a specific application and ambient temperature or range of temperatures expected to be encountered.

Today, most automobiles and trucks use multi-viscosity oils. Multi-viscosity petroleum oils are manufactured by starting with a lower viscosity base stock oil and blending in Viscosity Index Improvers (VI's). VI's were discussed in detail in section 4. The purpose of the VI's are to allow a lower viscosity oil, such as a SAE 10W oil to flow like a 10W oil at low ambient temperatures (such as during cold starting) and also flow like a SAE 30W oil at higher ambient and operating temperatures. The resultant formulation is called a multi-viscosity oil, and in this example, would be called a SAE 10W-30.

There are certain applications that a multi-viscosity petroleum oil is not optimum for as discussed in section 3, and will be repeated on the next page due to the critical importance that you understand this concept. Applications such as high RPM, high load small engines such as lawn mowers usually are specified to use a SAE 30W petroleum oil, although the owners manual never specifically states petroleum oil. Some high horsepower racing or diesel engines also may be recommended to use a SAE 30W or SAE 40W petroleum oil by a particular engine manufacturer or builder.

The problem that can occur in **petroleum based motor oils with VI's** is that under heat, load and shear forces the molecules of the VI tend to change shape from a round shaped molecular structure to a straightened, or aligned, molecular structure. When this occurs the VI's are subject to degradation due to shear forces created inside the engine, which can cause a temporary loss of the oils specified viscosity. Under shear loads the molecules in the VI's align themselves in the direction of the shear stresses so there is less resistance to flow. As the oil cools and the shear forces are no longer present the VI's return to their original molecular configuration and the original viscosity is returned to the oil. **Where serious problems can occur are under extreme heat and shear loads where the molecular structure of the VI's are permanently destroyed and will not return to their original configuration when the oil cools and shear stresses are no longer present.** This is the prime reason that, as discussed previously, small engine manufacturers and certain specific diesel engine manufacturers specify a straight weight **petroleum oil** with no VI's.

WHAT ABOUT ENGINES THAT "REQUIRE" A STRAIGHT WEIGHT OIL?

While we are on the subject of oil shearing I though it appropriate to discuss this topic. I get many calls asking why manufacturers of small engines, such as used in lawn mowers, generators and even some larger diesel engines or racing engines "require" either a SAE 30 or SAE 40 oil. The reason, as stated previously, is that first and foremost, **they are referring to a petroleum motor oil**.

These types of engines operate under extreme RPM, load and heat and in the case of small engines are mainly air-cooled. Multi-viscosity petroleum oils are full of viscosity improvers (VI's). It is these viscosity improvers that are the weak link. As these agents are subjected to heat, load and high RPM the oil cannot reach its intended high temperature viscosity, which results in shearing. As this shearing continues the results can be loss of oil film strength, increased wear rates and temperatures and oil consumption issues. That is the reason straight weight **petroleum oils** are recommended for these types of applications.

When a premium quality multi-viscosity synthetic oil, such as a 10W-30, 10W-40 or 15W-40 oil is used these concerns are non-existent. **Synthetic oil is incredibly shear resistant.** The bottom line is that the manufacturer's specifications are based on petroleum oils, yet your owner's manual is not going to explain that, so you in turn go out looking for the "required" straight weight petroleum oil. You would be much better off using a premium quality synthetic oil in these type of applications. Synthetic oils will be covered in detail in later sections of this book.

The problem is that, although synthetic oils are becoming much more widespread in use, almost all automobile and equipment owners manuals are written in reference to petroleum oil viscosities and specifications yet they do not specifically state this. If the specifications and recommendations were changed to include synthetic oil there would be no need to have 4 or 5 different viscosity oils listed, for example, for different ambient operating temperature conditions. One multi-viscosity synthetic oil would cover everything from extreme cold to extreme heat.

Automobile and equipment manufacturers in the U.S. are slowly coming around as they realize more and more of their customers will change to synthetic lubricants. Some automobile manufacturers use synthetic oil as a factory fill on specific high performance models. Others only use synthetics where it is needed to solve a problem, typically heat or wear related.

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9. API SERVICE QUALITY CLASSIFICATIONS

The API is the **A**merican **P**etroleum **I**nstitute. The API maintains a system of **S**ervice Classifications ("**S**" ratings) for gasoline engines and **C**ommercial Classifications ("**C**" ratings) for diesel engines. The procedures, procedures and policies by which lubricants are rated is a constantly changing system and involves representatives from the major automotive companies, API, oil manufacturers other engineering activities. Periodically changes are made to the specifications to keep up to date with current gasoline and diesel engine technology.

There are many classifications that have become obsolete and are no longer used. For example, occasionally I receive calls from people that have purchased a new piece of equipment stating they have to use a "SE" oil. I explain to them that SE oil specifications began in 1971 and were obsolete with the new SF specifications released in 1981. Today both SE and SF are obsolete. What has most likely happened is that some technical editor or clerk has transcribed portions of a previous service or owners manual to the new manual without completely reviewing it for any errors or updates to specifications.

The specifications referred to in these classifications generally have to do with oxidation protection, high temperature engine deposits, foaming, acid formation, sludge control and rust and corrosion protection. I have listed only the most recent classifications. There are many obsolete specifications that will not be covered in this book. These specifications are constantly changing and are subject to change as new engine, emissions and vehicles and/or government requirements arise. Note that when a new specification is released it makes the previous specification obsolete, therefore when an applications specifies the obsolete lubricant you may use the lubricant with the API classification that has superceded and replaced it

"S"- SERVICE CLASSIFICATIONS FOR GASOLINE ENGINES

<u>SH- For 1994 Gasoline Engine Service (obsolete spec.)</u>

Classification SH was adopted in 1992 and recommended for gasoline engines in passenger cars and light trucks starting in 1993 model year. This category supercedes the performance requirements of API SG specification for 1989-1992 models, which is now obsolete. Applications that call for an API service classification SG can use the SH specification. The specification addresses issues with deposit control, oxidation, corrosion, rust and wear and replaces.

<u>SJ- For 1997 Gasoline Engine Service (current spec.)</u>

Classification SJ was adopted in 1996 and recommended for gasoline engines in passenger cars and light trucks starting in 1997 model year. Applications specifying API SH can use the newer API SJ service classification. Note that where applicable certain letters in the sequence will be skipped to prevent confusion with other standards. In this case, SI was skipped since industrial oils are currently rated according to SI classifications.

SL- For 2001 Gasoline Engine Service (current spec.)

Recommended for gasoline engines in passenger cars and light trucks starting in July 2001. SL oils are engineered to provide improved high temperature deposit control and lower oil consumption. Applications specifying API SJ can use the new API SL service classification. Note that some SL rated oils may also meet the latest ILSAC specification and/or qualify as energy conserving. SL is the latest specification.

SM- 2004 Gasoline Engine Service (current spec.)

Introduced in Nov. 2004, SM oils provide improved oxidation resistance, deposit protection, wear protection, and improved low temperature performance over the life of the oil. Note that some SM oils may also meet the latest ILSAC specification.

"C"- COMMERCIAL CLASSIFICATIONS FOR DIESEL ENGINES

CF-For 1994 Off-Road Indirect Injected Diesel Engine Service

API Service Category CF denotes service typical of off-road, indirect injected diesel engines and other diesel engines that use a broad range of fuel types, including those using fuel with higher sulfur content (over 0.5% wt sulfur fuel). Effective control of piston deposits, wear and corrosion of copper-containing bearings is essential for these engines, which may be naturally aspirated, turbocharged or supercharged. Oils designated for this service may also be used when API Service Category CD or CE is recommended. CF is a current specification.

CF-2- FOR 1994 Severe Duty 2-Stroke Cycle Diesel Engine Service

API Service Category CF-2 denotes service typical of two-stroke cycle engines (such as Detroit Diesel) requiring highly effective control over cylinder and ring-face scuffing and deposits. Oils designated for this service have been in existence since 1994 and may also be used when API Service Category CD-II is recommended. These oils do not necessarily meet the requirements of CF or CF-4, unless they pass the test and performance requirements for these categories. CF-2 is a current specification.

CF-4- For 1990 Diesel Engine Service

Service typical of severe duty turbocharged, 4-stroke cycle diesel engines, particularly late models designed to give lower emissions. These engines are usually found in on-highway, heavy-duty truck applications. API CF-4 oils exceed the requirement of CE category oils and can be used in place of earlier CC, CD and CE oils. CF-4 oils provide for improved control of piston deposits and oil consumption.

The CF-4 classification meets Caterpillar's 1k engine requirements, as well as earlier Mack Trucks (T-6 & T-7) and Cummins (NTC-400) multi-cylinder engine test criteria. When combined with the appropriate "S" category, they can be used in gasoline and diesel powered cars and light trucks as specified by the vehicle and/or engine manufacturer.

CG-4- For 1995 Severe Duty Diesel Engine Service

API Service Category CG-4 describes oils for use in high speed, four-stroke cycle diesel engines used in highway and off-road applications, where the fuel sulfur content may vary from less than 0.05% by weight to less than 0.5% by weight. CG-4 oils provide effective control over high temperature piston deposits, wear, corrosion, foaming, oxidation stability and soot accumulation. These oils are especially effective in engines designed to meet 1994 exhaust emissions standards and may also be used in engines requiring API Service Categories CD, CE and CF-4. Oils designated for this service have been in existence since 1995. CG-4 is a current specification

CH-4- For 1999 Severe Duty Diesel Engine Service

API Service Category CH-4 describes oils for use in high speed, four-stroke cycle diesel engines used in highway and off-road applications. CH-4 oils provide effective control over engine deposits, wear, corrosion, oxidation stability and soot accumulation. These oils are especially effective in engines designed to meet 1999 emission standards and may also be used in engines requiring API Service Category CG-4. Oils designated for this service have been in existence since 1999. CH-4 oils are engineered for use with diesel fuels ranging in sulfur content up to 0.5% weight. CH-4 is a current specification.

CL-4- For 2002 Severe Duty Diesel Engine Service

API Service Category CL-4 describes oils for use in those high speed, four-stroke cycle diesel engines designed to meet 2004 exhaust emissions standards and was implemented in October 2002. These oils are engineered for all applications where diesel fuel sulfur content is up to 0.05% by weight. These oils are very effective at sustaining engine durability where EGR (Exhaust Gas Recirculation) and other exhaust emissions systems are used and provide for optimum protection in the areas of corrosive wear, low and high temperature stability, soot handling properties, piston deposit control, valvetrain wear, oxidative thickening and foaming and viscosity loss due to shear. API CL-4 oils are superior in performance to those meeting API-CH-4, CG-4 and CF-4 and can be used and will effectively lubricate diesel engines specifying those API service Classifications

CL-4 PLUS was introduced in 2004 as an enhanced CL-4 category oil designed to meet specific soot control requirements of certain diesel engines.

CJ-4 For 2007 Severe Duty Diesel Engine Service
API Service Category CJ-4 describes oils for use in 2007 diesel engines with new EGR (Exhaust Gas recirculation) systems and particulate filters on the exhaust systems. Oils meeting this specification are designed to meet tough new NOx (nitrogen oxide) environmental regulations for 2007 and later model diesel engines.

COMBINED API SERVICE CLASSIFICATIONS

Most motor oils are currently available in combined API Service Classifications. The combined classification is a high quality oil that is formulated with the proper base stocks and additive package to provide protection for both turbocharged gasoline and diesel powered engines in severe service applications.

Combined API Service Classification motor oils are highly effective at reducing and controlling sludge and varnish deposits, acid and foam formation and have improved oxidation stability. An example of a combined API Service Classification is API SH/CG-4.

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10. API LICENSING

There are some motors oils that are API licensed and some that are not. There is a lot of misinformation about exactly what API licensing means and whether or not consumers have to use an API licensed oil.

When a particular motor oils displays the API starburst symbol that indicates the motor oil has passed basic **performance standards** in relation to specific laboratory tests and that a license fee has been paid for and that certain tests have been run. This does not mean that the lubricant is a quality lubricant or that it is not a quality lubricant; it simply means that the oil has passed certain requirements. Do not confuse this with oils that meet API Service Classifications, as discussed in the previous section. An oil can still meet API Service Classifications, but not be API licensed.

There are some oil companies that choose not to license their oils by the API. They feel that by doing so they have to follow API guidelines, which in effect limit how they can formulate a particular motor oil as well as whom they can purchase chemical or chemical formulations from and also limit future changes or improvements without re-certification.

One particular oil manufacturer I know of that choose not to license their oils by the API indicate that API licensing requirements are not consistent with their superior quality standards for the motor oils performance. If the API ever decides to improve its performance standards to be consistent with the superior quality this manufacturer demands, then they may consider to become API licensed (bb).

There are several top quality, non-API licensed motor oils on the market that have been proven to out-perform and out-protect **any** API licensed oil. And, you do not have to use an API licensed oil to “maintain your new vehicle warranty”, contrary to what many automobile dealership personnel may lead you to believe. Your warranty cannot be “voided” simply because you choose to use a non-API licensed motor oil, a brand different from what they recommend, a drain interval different from what they recommend or even a viscosity or type of oil different from what is recommended.

Besides, dealership personnel are not tribologists (lubrication engineers) and know very little, if anything at all, about lubrication science and engineering. The **only** way a warranty can be voided is due to an oil related failure that is proven to be oil related by laboratory chemical analysis and submitted in writing with documentation to substantiate the oil related failure.

The subject of manufacturer’s warranties and the brand or type of oil you choose to use will be covered in detail in section 19.

Email author: dave@performanceoiltechnology.com

11. ILSAC, JASO AND GF OILS

You may have noticed relatively new performance standards appearing in your owners manual, advertisements, articles and/or on bottles of oil, such as ILSAC, EOLCS, JASO and GF-2, GF-3 and GF-4 yet you have absolutely no idea what they mean and how they pertain to your vehicles performance and lubricant specifications.

Here's a brief rundown on what each organization does and how it affects the oil used in your vehicles.

Up until 1992 there were only three organizations that set specifications and classified oils for passenger cars, light trucks and commercial vehicles. These organizations are the American Petroleum Institute (API), which I am sure you are familiar with the API starburst insignia. The API is responsible for essentially administering the licensing and certification of engine oils and also developing the wording of new engine oil specifications. These new specifications are implemented at the request of the automakers when they determine that a particular specification or multiple specifications does not meet their performance criteria for current production vehicles. The API has regular meetings and contact with the automakers and their engineering representatives.

The Society of Automotive Engineers (SAE) is the organization that actually defines the need for new oil specifications, in conjunction with the automakers and the American Society of Testing Materials (ASTM) is the organization that defines the performance parameters and targets for each specification developed by the SAE. The American Automobile Manufacturers Association (AAMA) is an organization mainly comprised of representatives from GM, Ford and Daimler-Chrysler, which also review industry developments and determines the need to certain performance specifications for the entire vehicle, as well as for lubricants. The Japanese Automobile Standards Organization (JASO) is an organization that sets performance specifications and determines test specifications for lubricants to be used in their vehicles and equipment.

Now, there are many more organizations such as the ACEA, ISO, AIAM, AAIA, etc…which I am not going to cover. The ones listed in the previous paragraph are the primary organizations and governing bodies that have the most impact on engine oil performance specifications.

In 1992 the AAMA and the JASO met and determined that the current system involving the SAE, ASTM and the API, called the tripartite system meaning three governing bodies, was much too slow in responding to the rapidly expanding and changing needs of modern day automobiles and light trucks only. The AAMA and JASO was concerned that this lack of timely response left them vulnerable to excessive warranty claims that could otherwise be reduced and/or avoided.

Therefore, they formed the International Lubricant Standardization and Approval Committee (ILSAC). The ILSAC was empowered to set minimum performance standards for gasoline powered passenger car and non-commercial light truck oils. The ILSAC and the tripartite system (SAE, ASTM & API) then joined together and formed the Engine Oil Licensing and Certification System (EOLCS). The EOLCS licenses oils approved through the ILSAC. The API provides the overall administration of the EOLCS system.

Now to compound things, a new specification called ILSAC GF was developed in order to meet the newest set of government regulations regarding fuel economy and long-term emission system performance and durability. The initial ILSAC GF-1 and API SH specification first appeared in 1996. In 1997 ILSAC GF-2 and API SJ specification was released which put increased demands on 0W-30, 0W-40, 5W-20, 5W-30, 5W-40, 5W-50, 10W-30, 10W-40 and 10W-50 motor oils in order to meet requirements for phosphorus content, low temperature operation, high temperature deposits and foam control.

ILSAC GF-3 and API-SL replaced ILSAC GF-2 and API-SJ in July 2001 with even more stringent parameters regarding long-term emission system durability and improved fuel economy as well as improved performance in the areas of volatility and deposit control, viscosity retention, additive depletion over the oils service life and reduced oil consumption rates.

The ILSAC GF-4 specification has not been officially released as of this writing, although drafts of the specification exist and the various governing bodies, oil manufacturers and automakers are meeting regularly to develop, test and release the newest specification. Current debate centers on the percent of phosphorus in relation to emission systems performance and wear protection in new and especially older vehicles. The spring of 2004 is the scheduled date that GF-4 rated lubricants will be on the market (s).

It should be noted that in spite of all these new performance parameters and regulations, these new formulation petroleum oils are only beginning to approach the performance and protection that premium quality synthetic lubricants have offered for years. In addition to offering performance parameters that meet and exceed these specifications there are also premium quality synthetic lubricants on the market that have extended drain interval specifications.

There are two brands of synthetic lubricants on the market that are engineered, tested and specified for 25,000 miles/1-year and one brand that is engineered, tested and specified for 35,000 miles/1-year for the 0W-30 severe service synthetic. It seems that the automakers are reluctant to specify and release premium quality extended drain interval synthetic lubricants. In certain instances where there is a performance or durability issue synthetics will be used or in certain specialty or high performance vehicles.

This is certainly quite a complex organization of representation and to me it seems like too much involvement from various committees that have a lot of meetings and develop a lot of paperwork. What amazes me even more is the fact that these specifications they develop are primarily minimum or average performance specifications, especially when compared to the performance specifications of a premium quality synthetic oil.

A premium quality synthetic oil will easily meet and usually exceed these specifications. As I'm sure you can determine from my writing that I am partial to synthetic lubricants. I cannot understand why anyone would want to use a petroleum oil in any vehicle or piece of equipment when they can use a premium quality synthetic oil and get performance and protection benefits far beyond what even the best petroleum oil can deliver and save time and money in the process.

Now, you may have been wondering why I waited so long into this book to begin to discuss synthetic lubricants. The reason is that I wanted you to have a good understanding of lubrication principles, petroleum oil refining, manufacturing, additives, testing and specifications. Now that you have that knowledge it will make it much easier to understand why synthetic oils outperform petroleum oils and why synthetic lubricants are superior. The next several sections will be entirely devoted to synthetic lubricants.

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12. SYNTHETIC LUBRICANTS HISTORY- PART 1

The following information was acquired during extensive research in the archives of a major auto manufacturers scientific research library and is documented in a Society Of Automotive Engineers (SAE) paper, which was presented at the SAE Annual Meeting in Detroit, Michigan, January 1946. The paper was written and presented by J.C. Kratzer of Linde Air Products Co., D.H. Green of National Carbon Co. Inc. and D.B. Williams of Carbon and Carbon Chemicals Corp.

Excerpts from this paper are listed below in order to accurately describe the history of synthetic lubricants. More recent developments in synthetic lubricants will be listed in the succeeding section of this book.

The initial compounds of synthetic lubricants were developed by Carbide and Carbon Chemicals Corp, Union Carbide Corp and Carbon Corp. and were initially subject to an order of secrecy by the Commissioner of Patents.

The original work was carried out at the Mellon Institute of Industrial Research by the Organic Synthesis Fellowship, which was sponsored by the Carbide and Carbon Chemicals Corp, in the early 1930's. Further development of these products was carried out by these two companies and research institute as well as at the labs of Linde Air Products Co., where automotive research work in connection with antifreezes and other automotive products had been conducted for many years.

These new synthetic lubricants were a development of American science and industry. They are not related to the synthetic lubricants developed in Germany. Those were primarily developed as a substitute for natural petroleum products, which were unavailable to the Germans during World War II. The new synthetics developed by American science and industry exhibited properties that were superior to the German products, and they differ from them chemically. These new synthetic lubricants were synthesized from natural or hydrocarbon gasses as raw materials. They contain no petroleum oil.

The first two series of synthetic lubricants were called LB Series and included five different types of synthetics, of which some were tested and used extensively in military aircraft and others were tested in automotive and military land vehicles. LB-300 was first marketed by National Carbon Co. Inc. (a unit of Union Carbide and Carbon Corp.) in two limited areas in the Eastern U.S. in the winter of 1946 for use in automobiles, busses, trucks and tractors. National Carbon Co. called the product Prestone motor oil, sharing the trademark of its well-known antifreeze.

LB-300 was superior to petroleum oils in many ways. It had a flash point of 470 deg. F., a fire point of 570 deg. F., a pour point of minus 40 deg. F., a carbon residue less then 0.01% and ash content of less than 0.01%. The new product was clearly superior to any petroleum oil of that era, but still there were many questions that needed to be answered such as: Is it a good lubricant? Is it resistant to oxidation? How does the wear of the engine compare with the best petroleum oils? Does an engine consume more oil? Does it corrode bearings and other parts of the engine? Does it permit easier starting under low temperature conditions? Does it form more or less sludge and varnish in an engine than petroleum oils?

The answer to these questions, although obvious now, was not known at the time. Therefore in addition to laboratory testing which had been in progress for several years, it was decided to perform extensive testing in automobiles both by employees of the company and by private individuals. Three privately owned trucking fleets were also used for testing. The data acquired was in addition to data that had been acquired from the U.S. Army Air Forces and the Army Ordinance Department.

In other early historical developments, synthetic oils consisting only of hydrocarbon molecules were first produced by the prominent chemists Charles Friedel and James Mason Crafts in 1877 (a). Standard oil Company of Indiana attempted to commercialize synthetic hydrocarbon oil in 1929 but was unsuccessful because of lack of demand. In 1931, Standard Oil disclosed a process for the polymerization of olefins to form liquid products. At about the same time the work that the work at Standard Oil was being carried out Farben Industries independently discovered the same process (a).

The first use of a linear alpha-olefin to synthesize an oil was disclosed in a patent issued to Gulf Oil Company in 1951. The use of free-radical initiators as alpha-olefin oligomerization catalysts was first patented Mobil Oil in 1960. In 1968 Mobil Oil patented a process for the oligomerization of alpha-olefins using a special catalyst system (a).

AMSOIL INC. began developing and testing synthetic lubricants starting in the mid-1960’s and was the first company to formulate a synthetic oil to meet API service requirements. The commercial development of PAO fluids as lubricants and high-performance functional fluids began in the early 1970’s, but significant growth in markets and in the variety of end-use applications did not begin until the latter part of the 1980’s. During that time a handful of companies played significant roles in both the research and development and market development efforts. The companies include Mobil, Gulf Oil Company, Chevron, Amoco, Ethyl Corp., Exxon Corp, Quantum Chemical Corp., Castrol Limited, Uniroyal Chemical Co., Neste Chemical, Texaco and Shell Chemical (a).

I am not going to continue here and review the data from test fleets as the purpose of this introduction to synthetic lubricants is specifically to outline the initial development and history of synthetic lubricants. From the period of initial development up until the late 1960’s to early 1970’s, synthetic lubricants were primarily used by the military, industry and in aircraft jet engines. Although synthetic lubricants had been extensively tested both in the laboratory and under actual fleet conditions, private motorists continued to use standard petroleum oil for their cars and trucks. More recent developments in synthetic lubricants are included in the following section. Email author with any questions: dave@performanceoiltechnology.com

13. SYNTHETIC LUBRICANTS HISTORY- PART 2

During the mid1960's and early1970's here were two main companies that led the development, testing and release of synthetic motor oils for automobile engines to be sold via the retail market. These two companies are AMSOIL INC. and Mobil Oil Corp. AMSOIL INC. developed the first synthetic motor oil to meet API service requirements for automobile engines and also has been authorized to register and use "The First in Synthetics" as an official trademark by the U.S. Patent and Trademark office. The first can of AMSOIL 10W-40 appeared on the market in 1972. Mobil synthetic appeared on the market in 1975. The technology for Mobil's product was based on a variation of their "XRN 1669" synthetic motor oil, which they had been testing for several years prior to its release. Although, both products were far superior to petroleum oil, widespread use and acceptance of these new breed of lubricants was relatively slow in the beginning.

As a side note to the previous description, you may have at one time or another heard Mobil advertised as being the first company to develop and release a synthetic motor oil for automobile engines. The historical facts are that AMSOIL INC. was the first to **develop and market** an API rated synthetic motor oil for automobile engines, but Mobil was the first to **nationally market** their new synthetic motor oil. AMSOIL was nationally marketed right after Mobil began nationally marketing their new oil.

Other major oil companies were extremely slow to follow and rather than develop synthetic lubricants of their own for use in automobile engines via the retail market, they generally tried to discredit the benefits of synthetic motor oils to consumers for about the next 15-20 years. When the public could no longer be convinced that petroleum oil was a better choice and the demand for synthetic motor oils was rising quickly, other oil companies developed their own "revolutionary" formulation of synthetic motor oil for automobile engines and started advertising the exact same benefits that they were previously not promoting. Note that many of these companies did have laboratory and field experience with synthetic formulations and many also had synthetics available that were used in specialized industrial, diesel, jet and military applications, but nothing you could go buy at your local auto parts store.

Regardless, the lead that AMSOIL, as well as Mobil, had on the competition was a large one and the other oil companies played "catch-up" but to date, have still not released a synthetic lubricant for retail sale in automobile engines that matches the performance of AMSOIL. Note that although I have my personal preferences, I am not recommending one product over the other in this book. I am simply stating facts and data as referenced by historical documentation and laboratory tests. There are major performance differences between AMSOIL's and Mobil's synthetic oil. I will review the latest laboratory test data for both in section 27.

Also, note that the reason I am focusing on these two companies is because they were the innovators of synthetic motor oil for widespread automobile engine use **via the retail market**. The other major oil companies were about 15-20 years behind in bringing synthetic motor oils to the retail market. By the mid 1990's mostly all of the major oil companies offered synthetic motor oil in addition to their petroleum oil products. They did so finally when (in my opinion) they realized that their profits were going to be negatively affected if they didn't release a synthetic of their own. The synthetics that they released and which are on the market today, when tested according to ASTM test procedures and specifications, do not even come close to matching the performance of AMSOIL.

Mobil also does fairly well in certain test parameters, but you have to look at the comparison data and the differences become apparent. Other companies marketing synthetics do, however, have very convincing and catchy ad campaigns and slogans. Don't be fooled; ask to see the ASTM test results and data for specific parameters which were covered in the Lubricant Testing section of this book (section 6). There are only a few companies that publish these results, but still I recommend you contact their technical department or customer service department and request to see the data. If they can't supply the technical data, as tested by ASTM certified independent laboratories, then I would be highly suspect of their claims. Additionally, if you desire you can take samples of any oil and submit it to a certified ASTM test lab for analysis. It will be somewhat costly to run all the tests, but it certainly can be done.

The results of Mobil's testing are documented in SAE Paper 750376 by Mobil Research and Development Corp, from 1975. The paper is entitled "An Engine Oil Formulated for Optimized Engine Performance". This paper was presented at the February 1975 SAE Automotive Engineering Congress and Exposition, Detroit, Michigan. The conclusions from this paper are as follows (note that this 1975 data is still perfectly valid today):

1. Lubricant reformulation can help modern engine performance in a number of important areas. A light viscosity engine oil has been formulated utilizing a combination of specific synthesized base stock materials. This lubricant, XRN 1669, has been shown to provide performance superior to premium quality SAE 10W-40 mineral oils in the following areas:
    a. Engine Cleanliness
    b. Fuel Economy
    c. Oil Economy
    d. Cold Starting Capability
    e. Intake System Cleanliness
    f. Shear Stability
    g. Thermal/Oxidative Stability

2. Excellent wear protection, at least equivalent to that of premium quality SAE 10W-40 mineral oils, was provided by XRN 1669, while an ashless, non-phosphorus engine oil, meeting API SE wear requirements gave high wear in a laboratory test, as well as in a field evaluation.

3. Engine oils formulated with this mixed base stock system are completely compatible with mineral oils and have no deterious effects on elastomeric seals commonly used in automotive engines.

4. Exhaust emission levels and octane number requirement increase were found to be independent of engine oil sulfated ash content and base stock material for the lubricants tested and driving conditions employed.

It is important to recognize that AMSOIL INC. developed the first synthetic motor oil in the world to meet API service requirements. Lieutenant Colonel Albert J. Amatuzio, President and CEO of AMSOIL INC., had ample opportunity to witness synthetic lubricants in action as a jet fighter squadron commander. Synthetic oils were, and still are, used exclusively in jet engines because of their extraordinary performance characteristics to reduce friction and wear on engine components, their ability to function dependably at severe hot and cold temperature extremes and their ability to withstand rigorous and lengthy engine operation without chemical breakdown.

Al Amatuzio recognized that these same benefits would prove invaluable in automobile engines and he went on to formulate the first synthetic motor oil in the world to meet API service requirements. The release of his new and revolutionary synthetic motor oil in 1972 outperformed every other oil on the market and signaled the birth of an entire industry. Al Amatuzio was officially recognized for his outstanding developments by *Lubricants World Magazine* in a Feb. 1994 when he was inducted into The Lubricants World Hall of Fame. Amatuzio is credited with pioneering synthetic motor oil for use in automobile engines.

The exact same benefits that are listed above are just as important today as they were in the early days of synthetics and are still a major benefit of synthetic lubricants. Petroleum oil cannot even come close to comparing to the benefits provided by a premium quality synthetic lubricant.

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14. WHAT ARE SYNTHETIC LUBRICANTS

Now that you know the history of synthetic lubricants I will cover what synthetic lubricants are and what they are made from for some of the most common types of synthetics. There are literally hundreds of types of specialized synthetic base stocks in existence and it is far beyond the scope of this book to cover them all. Highly specialized chemistry and scientific books exist on this topic for anyone interested in more in-depth research, but unless you have an extensive knowledge of chemistry they aren't going to be very useful to you and the books very expensive are primarily only available in the research libraries of corporations involved in the synthetic lubricants engineering and manufacturing business.

A synthetic lubricant is a product that is made from a chemical reaction (synthesis) of two or more simpler chemical compounds and also containing the necessary performance additives. The base stocks that form a synthetic lubricant are tailored through molecular restructuring in order to meet specific physical and chemical characteristics (r) (u).

Some of the most common synthetic lubricants are listed below

1. Polyglycol fluids- Polyalkylene Glycol, Polyglycol Ethers, Polyalkalylene Glycol Ethers
2. Silicones
3. Esters: Diesters (Dibasic Acid Esters)
4. Esters: Polyolesters (Neopentyl Poly Esters)
5. Polymerized alpha olefin: Polyalphaolefin, Olefin Polymers, Olefin Oligomers- synthetic hydrocarbons
6. Alkylated Aromatics- Dialkylbenzenes- a synthetic hydrocarbon
7. Phosphate Esters

There are many hundreds more types of synthetic lubricants and chemical variations of these synthetic lubricants. **There is also no one specific synthetic lubricant that is superior in all respects, although a particular synthetic lubricant may possess certain specific advantages for a specific application**. The synthetic lubricants listed in this book account for the majority of the volume of synthetic lubricant base stocks now used.

Some of the common applications of each type of synthetic lubricant as well as the general process that the synthetic is manufactured where applicable are listed below:

Polyglycols

These synthetic fluids were among the earliest used where extremes of temperature were encountered. The first use of polyglycols was for a water based hydraulic fluid for the U.S. Navy in 1943 for use in military aircraft so that fires would not result if bullets or shrapnel severs hydraulic lines (a).

They have good lubricity, low sludge deposits, high natural viscosity indexes and good temperature stability. Typical applications include automotive hydraulic brake systems (ethylene and polyethylene glycol), industrial gear oils, fire resistant fluids (by mixing the polyglycol with water), greases, metal working fluids and gas compressor oils. Polyglycols were tested extensively for automobile engines but never developed into widespread use. Polyglycols are not compatible with petroleum oil. The chemical process used to manufacture polyglycols is beyond the scope of this book and is highly complex and one would need to be chemist or engineer to fully understand the process

Silicones

Silicones have high viscosity indexes and high thermal stability as well as excellent low temperature performance, which makes them good for use in certain greases, torsion dampers and in automotive brake hydraulic systems. Silicone brake fluids have excellent temperature stability in newer vehicles, which have high performance brake systems but they are not nearly as water tolerant as Polyglycol brake fluids. Water gets in brake systems over a period of time through the hydraulic lines, fittings and breather cap. As little as 2-3% water in a brake system is enough so that it can cause brake concerns. Silicone brake fluid and Polyglycol brake fluid are not compatible with each other and serious brake performance concerns can result if the two are mixed together. Additionally, the higher the temperature/performance rating of a brake fluid, regardless if it is Polyglycol or Silicone, the higher the affinity of the brake fluid to absorb water.

Esters: Diesters (dibasic acid esters)

During World War II a range of synthetic oils was developed. Among these, esters of long-chain alcohols and acids proved to be excellent for low temperature lubricants. Following World War II, the further development of esters was closely linked to the aviation gas turbine. In the early 1960s, neopolyol esters were used in this application because of their low volatilities, high flash points and good thermal stabilities.

Diesters are prepared by reacting a dibasic acid with an alcohol containing one reactive hydroxyl group. Note that the hydrolytic stability of diesters is not as good as mineral oils. Hydrolytic stability refers to how the lubricant reacts in the presence of water. Hydrolytic degradation can lead to acidic products, which, in turn, promote corrosion. Plus, hydrolysis can also materially change the chemical properties of the base fluid, making it unsuitable for the intended use. Systems that can contract high levels of moisture include systems that operate at low temperatures or that cycle between high and low temperatures and also certain fuels such as racing engines running alcohol, which has a cooling effect in the engine. Racing engines using ester based lubricants should have the lubricant changed regularly.

Diesters have good lubricating properties, good thermal and shear stability, high viscosity indexes and have exceptional solvency and detergency. Diesters are superior fluids for aircraft engines and compressors, although mainly older jet aircraft. Diesters are also used as a base oil or part of a base oil for automotive engine oils and in some low temperature greases (note: modern military and commercial jet aircraft almost universally use lubricants formulated with polyol esters as the base fluid now).

Diesters are incompatible with some sealing materials and can cause more seal swelling than mineral oils. The scientific reason for this is as follows: diesters have a low molecular weight that results in low viscosities. This combined with their high polarities makes them quite aggressive to elastomeric seals. This can be reduced by using better elastomers or by carefully blending with PAO's to nullify their swelling effects, since PAO base stocks are nonpolar (a) (d).

Esters: Polyolesters (Neopentyl Poly Esters)

Polyol esters are formed by reacting an alcohol with two or more reactive hydroxyl groups. These fluids are used primarily for aircraft engines, high temperature gas turbines, hydraulic fluids and heat exchange fluids. Polyol esters are much more expensive than diesters. Lubricating greases with polyol esters as the base fluid are particularly suited to high temperature applications. Polyol esters have the same advantages/disadvantages as diesters. They are, however, much more stable and tend to be used instead of diesters where temperature stability is important. In general, a polyol ester is thought to be 40-50 deg. C. more thermally stable than a diester of the same viscosity. Esters give much lower coefficients of friction than those of PAO and mineral oil. By adding 5-10% of an ester to a PAO or mineral oil the oil's coefficient of friction can be reduced markedly (a) (d).

Polymerized alpha olefin: Polyalphaolefin, Olefin Polymers, Olefin Oligomers- a synthetic hydrocarbon

PAO's are commonly used to designate olefin oligomers and olefin polymers. The term PAO was first used by Gulf Oil Company (later acquired by Chevron), but it has now become an accepted generic term for hydrocarbons manufactured by the catalytic oligomerization of linear alpha olefins having six or more carbon atoms. PAO's are gaining rapid acceptance as high-performance lubricants and functional fluids because they exhibit certain inherent and highly desirable characteristics (a). These favorable properties include:

A wide operational temperature range.
Good viscometrics (high viscosity index).
Thermal Stability.
Oxidative Stability.
Hydrolytic stability. *
Shear stability.

Low corrosivity.
Compatibility with mineral oils.
Compatibility with various materials of construction.
Low toxicity.
Manufacturing flexibility that allows "tailoring" products to specific end-use application requirements.

* Of particular interest in relation to demonstrating superior hydrolytic stability of PAO fluids is a test that was conducted to find a replacement for a silicate ester based aircraft coolant/dielectric fluid used by the U.S. military in aircraft radar systems (a). The test method required treating the fluids with 0.1% water and maintaining the fluid at 170 or 250 deg. F. for up to 250 hours. Samples were withdrawn at 20- hour intervals, and the flash points were measured by the closed cup method. A decrease in flash point was interpreted as being indicative of hydrolytic breakdown to form lower-molecular-weight products. The PAO showed no decrease in flash point in any of the test conditions, while the silicate ester based fluid showed marked decreases (a). The PAO fluid maintained started out with a flash point of 300 deg. F. and only dropped to 295 deg. F. at 80 hours into the test, while the silicate ester fluid, which started out with a flash point of 270 deg. F., ended up with a flash point of 220 deg. F. at only 55 hours into the test.

PAO's are used extensively as automotive lubricants (engine, gear, transmission, grease, hydraulic). PAO's are also super premium oils for automotive applications operating in temperature extremes. PAO's are a synthetic hydrocarbon that is compatible with mineral oils. In industrial applications, they may be combined with organic esters to be used in high temperature gear and bearing oils, as well as gas turbines. They are also used as a base fluid in some wide temperature range greases (d).

The general manufacturing process used to form PAO's is performed by combining a low molecular weight material, usually ethylene gas, into a specific olefin which is oligomerized into a lubricating oil material and then hydrogen stabilized. There are a variety of basic building block molecules used to form the finished lubricant, which are dependent on the range of requirements of the specific lubricant.

Seal compatibility is an important factor for any lubricant. Unlike mineral oils, PAO does not have a tendency to swell elastomeric materials. Early commercial PAO products were not formulated properly to allow for this difference in behavior. Consequently, early PAO's gained an undeserved reputation for leakage. Extensive tests have since shown that the addition of small quantities of an ester to the formulation easily alleviates this problem (a).

Recent work has indicated that the proper choice of other performance additives may eliminate the need to employ esters, but this approach is not yet in practice for crankcase applications. In a test of a PAO vs. a mineral oil for seal compatibility, four seal materials were studied: acrylate, silicone, nitrile and fluoroelastomer. The seals were evaluated at the end of the test for changes in tensile strength, elongation, volume (seal swell), and hardness. The PAO performance fell within the specification limits for all four elastomers. The mineral oil failed with silicone. Similar tests have been carried out with fully formulated part- and full-synthetic PAO oils. In all cases the fluids met the specifications (a).

Recent data shows that PAO-based fluids provide superior performance for the high-tech cars and trucks being built today. Today's engines are smaller and more demanding and operate at higher RPM's and under hood spaces is limited which causes increased operating temperatures. Both the thermal conductivity and heat capacity of PAO fluids are about 10% higher than values for comparable mineral oils (a). The net result is that PAO-lubricated equipment tends to run cooler.

Alkylated Aromatics- Dialkylbenzenes- a synthetic hydrocarbon

This synthetic hydrocarbon is compatible with mineral oils and is used as a base oil in many industrial applications such as engine, gear, hydraulic, air compressor and gas turbine fluids and in greases for sub-zero applications. These fluids are somewhat toxic and have poor biodegradability (d).

This lubricant is formed by the alkylation of an aromatic compound, usually benzene. Alkylated aromatics have excellent low temperature fluidity. Their viscosity indexes are marginally higher than a high viscosity index mineral oil and they are oxidation resistant and stable at high temperatures and hydrolytically stable.

Alkylated aromatics were developed for functional fluid use as early as the 1928-1936 time period but failed to gain any commercial prominence. There was some development and use of these fluids by the Germans from 1942-1945 due to petroleum oil supply interruptions cause by the war, but the war ended before they could get production volume increased to what they required (a).

It wasn't until the search for oil in Alaska and Canada in the 1960's and the construction of the Alaska pipeline in the 1970's that the good low temperature properties of alkylated aromatics became important. Conoco was the major company behind the introduction of alkylated aromatic base stock lubricants for service during this era (a).

Phosphate Esters

The major feature of these fluids is their fire resistance. They find extensive use as hydraulic fluids in aircraft hydraulic systems, underground mining hydraulic systems, high temperature compressors and steam turbines, where fire resistance is critical. They have poor compatibility with some sealing materials and most paints (d). The manufacturing process of phosphate esters is extremely complex and will not be covered in this book. Where safety is critical and there are high operating temperatures and/or pressures, phosphate esters are the lubricant of choice.

Summary

There is clearly no doubt that synthetic lubricants are superior to petroleum based oils. An excellent summary of in-depth studies that were conducted on the benefits of synthetic lubricants is presented in Appendix B of the Society for Automotive Engineers, Progress in Technology Series 22 and was conducted during the 1970's and 1980's. The nine superior performance features of synthetic engine oils that were documented by extensive laboratory and field testing are listed below:

Nine Superior Performance Features of Synthetic Engine Oils

1. Engine Cleanliness.
2. Improved Fuel Economy (4.2% average increase)
3. Oil Economy (lower consumption)
4. Excellent Cold Starting and Low Temperature Fluidity
5. Outstanding Performance in Extended Oil Drain Field Service
6. High Temperature Oxidation Resistance
7. Outstanding Single and Double Length SAE-ASTM API "SE" and "SF" Performance Tests (note SE and SF specs were the latest at the time of the testing)
8. Excellent Wear Protection
9. Extended drain capability for heavy-duty diesel trucks and gasoline powered trucks (p). Note: this particular test was based on truck fleet testing, however extended drain capability holds true for passenger cars as well.

These same superior performance features of synthetic engine oils hold true today just as they did when this extensive testing was conducted and has since been verified by many more studies and testing as well as countless millions of miles of field service in every possible type of vehicle and equipment application.

Email author with any questions: dave@performanceoiltechnology.com

15. BASE OIL CATEGORIES AND DEFINITIONS

There are five specific categories of base oils. These categories define the type of base stock the oil is formulated from. The categories are as follows. Note that the base oil group category is followed by the manufacturing method (in bold print) and then a description of the oil characteristics for each category.

Group I - Solvent Freezing: Group 1 base oils are the least refined of all the groups. They are usually a mix of different hydrocarbon chains with little or no uniformity. While some automotive oils on the market use Group I stocks, they are generally used in less demanding applications (hh).

Group II - Hydro processing and Refining: Group II base oils are common in mineral based motor oils currently available on the market. They have fair to good performance in lubricating properties such as volatility, oxidative stability and flash/fire points. They have only fair performance in areas such as pour point, cold crank viscosity and extreme pressure wear (hh).

Group – III Hydro processing and Refining: Group III base oils are subjected to the highest level of mineral oil refining of the base oil groups. Although they are not chemically engineered, they offer good performance in a wide range of attributes as well as good molecular uniformity and stability. They are commonly mixed with additives and marketed as synthetic or semi-synthetic products. Group III base oils have become more common in America in the last decade (hh).

Group IV -Chemical Reactions: Group IV base oils are chemically engineered synthetic base stocks. Polyalphaolefins (PAO's) are a common example of a synthetic base stock. Synthetics, when combined with additives, offer excellent performance over a wide range of lubricating properties. They have very stable chemical compositions and highly uniform molecular chains. Group IV base oils are becoming more common in synthetic and synthetic-blend products for automotive and industrial applications (hh).

Group V - As Indicated: Group V base oils are used primarily in the creation of oil additives. Esters and polyolesters are both common Group V base oils used in the formulation of oil additives. Group V oils are generally not used as base oils themselves, but add beneficial properties to other base oils (hh).

Note that the additives referred to in the Group V description are not aftermarket type oil additives. The additives referred to are used in the chemical engineering and blending of motor oils and other lubricating oils by the specific oil company that produces the finished product.

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16. OIL, AIR & FUEL FILTRATION

One of the most important items involved in achieving maximum longevity and optimum performance from an engine is in how well the oil, air and fuel is filtered. The primary objective of oil, air and fuel filters are to eliminate the maximum quantity of abrasive particles. If these particles are not effectively filtered out the life cycle of the engine will be drastically reduced. The goal of this section is to identify and review the critical items you need to know about oil, air and fuel filtration so that you can make an informed decision regarding your choice of filtration products.

Note that I will not be covering tribological concepts of engine wear as it is beyond the scope of this book and is a subject in itself that research scientists that I work with spend their entire careers on and involves a requires high degree of knowledge of chemistry, science, physics and tribology to fully understand.

The job of an oil filter is to remove atmospheric contaminants, wear particulates caused during engine operation and particulates in the oil created during the combustion process. The sum of these contaminants, if not properly filtered can wreak havoc on an engine and drastically reduce its longevity.

These particulates include products from fuel and its components such as carbon. This product is caused by the transfer of combustion products from the fuel to the crankcase oil. Carbon and soot is the cause of many deposits found inside engines. Diesel engines in particular can have very high degrees of carbon and soot build up, especially if they are operating with a plugged air filter and under heavy load, since the quantity of air is drastically reduced. Although air filtration is extremely important whether the engine is operating on gasoline or diesel fuel, diesel engines consume much more air during operation than gasoline engines. Other deposits can be caused by oil diluted with fuel from poor combustion or from an improperly warmed engine where unburned fuel can blow by the piston rings and enter the crankcase.

Note that fuel and water are also sources of contaminants but are also very difficult to filter effectively and require additional filtration systems. Special by-pass oil filters are effective in filtering out water but fuel still remains a problem. It is very important to use a high quality fuel filter and change it according to recommendations. On diesel engines I highly recommend installing an auxiliary fuel filter/water separator because many original equipment fuel filters cannot remove sufficient quantities of water or the small sizes of particulate contaminants. Premium quality fuel filter/water separator units can remove virtually 100% of the water and contaminants.

The engine wearing during use also causes deposits. The resultant products of this type of wear include iron, lead, copper, tin, aluminum from bearing and bushing material and other metals such as chromium from piston rings and valve train parts. Other significant sources of engine oil contamination include silicon left inside the block from sand casting at the foundry, machining particles from manufacturing and certain coolants and additives and particulates introduced from faulty or worn sealing surfaces, especially seals such as front and rear crankshaft and water pump seals, gasket materials or sealants. Another often-overlooked area of particulate entry is the funnel or oil container itself. Oil containers are sealed at the factory but after opening one it is easy for dirt particles to accumulate around the opening or in the funnel used to direct the oil into the engine. I keep all my funnels perfectly clean in a sealed plastic bag in a cabinet and never out in the shop or garage where they can pick up contaminants. Once I have opened an oil bottle it also goes in the cabinet.

As a side note, you may wonder why sand from machining operations is not fully cleaned out during the preparation and assembly process. The manufacturer does attempt to get all casting and machining particles out but still, the fact remains that there are millions of microscopic peaks and valleys and surfaces and passageways inside a cast surface that these microscopic particles of sand and metals may become embedded and are not all cleaned out during the wash process. The most effective way to clean cast surfaces is with hot steam, water and an industrial soap solution. That's why when rebuilding an engine after machining the cylinders, regardless of how well you clean them with parts cleaner, carburetor cleaner, brake cleaner, etc., the most effective method is to use warm dishsoap and water to thoroughly clean all machined surfaces. Then after cleaning rub a lightweight oil on the parts to prevent the humidity in the air from causing corrosion.

I recall a project I worked on at an axle manufacturing plant where we developed a special paint to coat the axles after casting and machining, but prior to assembly. The entire axle housing was put on a conveyer and dipped in a special paint. The paint served two purposes; to prevent external corrosion for a specified time period under severe salt and atmospheric conditions and to seal the inside of the axle housing so that any machining and casting particulates would not cause premature wear to the gears and bearings. The same theory holds true for engine blocks, however engine blocks are not painted internally.

The fact is that even with modern manufacturing practices there is still a certain amount of abrasives inside an engine from the manufacturing or rebuilding process. That is why filtration is so critical. In the absence of proper oil filtration these particles can be picked up and carried into circulation. One single particle embedded in a bearing is capable of causing appreciable damage.

The Effect of Used Oil Contaminants on Engine Wear (b)

The role of oil filters is, firstly, to remove all abrasive particles larger than a certain size, thus establishing a certain degree of filtration (more on this later). Given that general clearances between crankshaft and connecting rod bearings in modern automotive engines is between 0.0006-0.002 in. (15-50 microns) up to 0.003-0.004 in. (80-100 microns) in certain large industrial or diesel engines, and the thickness of oil film is between 5 and 75 microns with no load and 5 to 15 microns when fully loaded, steps should be taken to remove all hard particles with a diameter of more than 5 microns or at least those between 10 and 15 microns in diameter. This does not mean that smaller particles do not have any effect on wear. These size limits are also shown by numerous engine tests with dust particles of different sizes introduced into the crankcase oil. (c)

The test results show that:

- Abrasive particles between 0 and 5 microns cause significant wear
- The wear of all engine parts does not reach a maximum value for the same particle size.
- Wear of cylinder and rings reaches a maximum value with a smaller particle size than that causing maximum bearing wear. This appears to be due to the differences in clearances of these parts during running and also to the relative hardness of the metals used. Tests using a diesel engine fitted with a radioactive top ring illustrates the distribution of the size of metallic particles caused by actual ring wear during running:

- 55% of particles have a diameter of less than 8 microns
- 28% of particles have a diameter of less than 5 microns
- 7% of particles have a diameter of less than 1.2 microns
- 0.5% of particles have a diameter of less than 0.45 microns

These findings show that the metallic particles scraped off an engine play an appreciable role in the process of engine wear merely on account of their size. The finest particles, i.e. those between 0 and 5 microns and accounting for 28% of the total particles present, mainly have an abrasive and erosive effect on wear in the upper part of an engine (cylinders and rings) whereas 45% of the particles larger than 8 microns in diameter tend to act on the lower parts (bearings).

It is only through repeated passages of the oil through the oil filter that filtration is complete. A standard automobile engine filter fitted to a full-flow oil circuit shows a certain amount of dust passing the filter in its first passage through, i.e., 25% of particles between 10 and 20 microns, 15% between 0 and 10 microns, and 2% from 60 to 100 microns. It is the particles between 10 and 20 microns that are the most dangerous for engine wear and which must be removed as quickly as possible. The use of a second filter, or filtering in stages, may be useful provided the variation of load drop with time remains reasonable (b).

The following section will cover the various types of oil filters and how they function.

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17. OIL FILTERS AND OIL FILTRATION SYSTEMS

There are two types of oil filter elements and two types of oil filtration systems. These are surface oil filter elements, depth type oil filter elements and full flow and by-pass filtration systems.

Surface Type Oil Filter Elements

Surface type oil filter elements are the most common. In this type of system oil passes through only one layer of filtering media. This media is typically some form of pleated paper, paper-synthetic media or paper-fiberglass or a fully synthetic or fiberglass media. The paper is often treated with impregnants such as phenol resins and the impregnation is polymerized and the paper silicon treated. The purpose of this treatment is to increase the mechanical resistance of the paper, to even out channel patterns and to provide greater resistance under the corrosive effects of the oil (b).

The object of a pleated type surface element is to achieve maximum surface area inside a minimum volume. The specific pore size of the element is what determines the filters micron rating. However, the micron rating of a filter can be very deceptive. The general range of particle sizes that a surface type filter will stop is in the 10-40 micron range (d). The critical parameter is not what particle sizes a filter traps but at what efficiency it captures those particular particles (i.e., particle capture percentage).

Be very cautious of oil filters advertising a certain micron rating unless it also specifically states what efficiency it achieves at that micron size or shows a graph indicating the efficiency at various micron sizes. For example, a screen door could be stated to stop 1 micron particles from passing through, yet the percentage of the total 1 micron particles that a screen door will stop is going to be extremely small, and pretty close to zero.

Surface type oil filters are normally mounted in full flow applications, meaning that all that all of the lubricant in the circuit passes through the filter, but not necessarily through the media. This is due to the action of the bypass valve, which opens under certain circumstances (cold start-ups or pressure surges) and allows an uninterrupted flow of unfiltered oil while the valve is open (d). Another instance where the bypass valve will open is when a filter is filled to its maximum with particulates in which case unfiltered oil will be flowing to the engine.

I have seen some surface type filters on the market advertised as “10 micron” filters, for example. However, nowhere on the box does it state the efficiency rating, thus the “10 micron” value advertised is totally useless, and in my estimation, deceptive to the end user who may think they are actually getting a filter that stops all 10 micron particles. As an example, testing conducted at the Milwaukee School of Engineering, Fluid Power Institute using SAE Test Method J806 for filtration efficiency indicates the following at the lower end of the graph (j):

- Fram PH8A oil filter is 10% efficient a trapping 12 micron particles
- AC PF-2 oil filter is 10% efficient at trapping 4.5 micron particles
- Purolator PER-1 oil filter is 10% efficient at trapping14 micron particles
- Ford FL-1oil filter is 10% efficient at trapping12 micron particles.

At the upper range of the graph:

- Fram PH8A is 78% efficient at removing 20 micron particles
- AC PF-2 is 67% efficient at trapping 20 micron particles
- Purolator PER-1 is 42% efficient at trapping 20 micron particles
- Ford Fl-1 is 33% efficient at trapping 20 micron particles.

This test serves to show the wide variation in particle capture percentages for some common oil filters. The test also illustrates that the size range in which 60% of engine wear occurs is in the 5 to 20 micron range. This indicates that, in general, surface type flow oil filters are not very efficient at filtering out the particles that cause 60 % of engine wear. There are premium quality surface type full flow filters on the market that will outperform the filters used in this test. This also illustrates the need for by-pass oil filtration, which will be covered later. Note that in the same test a by-pass oil filter manufactured by AMSOIL INC. filtered out 100% of the 5-20 micron particles and about 85% of the1 micron particles.

AMSOIL INC. also manufactures the only Absolute Efficiency EAO Full Flow Oil Filters on the market. They utilize patented nanofiber technology and provide a filtering efficiency in accordance with industry standard ISO 4518-12 of 98.7 percent at 15 microns, while competing filters containing conventional cellulose medias range from 40 to 80% efficiency. The AMSOIL EAO Oil Filters are also the only oil filter on the market which recommends, specifies and guarantees 25,000 mile/1-year change intervals when used in conjunction with AMSOIL Synthetic Motor Oil.

Beta Ratings

The Beta rating of an oil filter is a measure of the particle capture percentage in a special test designed and specified by the Society of Automotive Engineers (SAE) and is referred to as test SAE J1858. The test measures the volume of particles that pass through a filter in a single pass vs. the total volume of particles introduced into the filtration system prior to entering the oil filter.

The percent efficiency of a filter with a specific beta rating is determined by subtracting one from the Beta rating, then divide the result by the actual Beta rating and multiplying the result of the division by 100. The final value determines exactly what percentage efficient a certain oil filter is at removing a specific size of contaminant.

Beta rating tests are the best way to accurately compare oil filter performance due to the fact that the test measures the specific oil filter's efficiencies at specific particle sizes.

Comparing filter micron ratings without knowing the efficiency at a specific micron particle size is meaningless.

Depth Type Oil Filter Elements

Depth type oil filters have elements that are constructed of materials that are referred to as "absorbent" and these consist of inactive materials such as cotton waste, waste paper, wound paper, cellulose, cloth, wood pulp, asbestos, etc., which are tightly packed together. These types of filters depend on the absorption of contaminants as the oil flows through the media. It takes quite a while for the oil to flow through a depth type filter. That is the reason that depth type oil filters are plumbed into an oil system as a secondary, or by-pass, oil filter. If they were plumbed into the full flow system the oil would take too long to flow through and the engine would not receive sufficient quantities of oil volume. Depth type filters typically do not have bypass valves since they are not plumbed into the full flow oil system. If a depth type oil filter plumbed in a system as a bypass filter became plugged the full flow oil filter would remain functional. Many poorly constructed absorbent depth filters are susceptible to a condition called channeling. Channeling is a condition whereby the oil flow through the media creates a "channel" or locates a path of least resistance. Once channeling occurs, effective filtration ceases (d).

Depth type absorbent filters will not remove oil additives (unless the additive is a solid lubricant such as graphite and the particle size is in the size range which may prevent them from moving through the filter) (d).

Another group of materials used in some depth type filters are referred to as "adsorbent" and consist of chemically active materials such as Fullers earth, clays, charcoal and chemically treated paper. **These filters remove contaminants through a chemical reaction with the lubricant, and as a result, may remove some oil additives** (d).

I do not recommend adsorbent type depth filters since they cannot selectively filter out only the harmful materials but in the process may filter out necessary additives that were engineered into the oil by the oil manufacturer.

Full Flow Oil Filtration Systems

Full flow oil filtration is the type that is used on almost every major automobile and light truck in production, as well as many other medium and heavy-duty trucks. In a full flow system all of the oil from the oil pump must pass through the oil filter. Filters used in this type of system must have a high degree of single-pass efficiency and a low restriction to oil flow. What this means is that the filter must be effective at removing engine damaging particulates from the engine oil the first time it passes through the oil filter.

In order to ensure that the engine is properly lubricated under all operating conditions and if the filter becomes plugged, a bypass valve is engineered into the oil filter or on some vehicles a pressure-regulating valve is designed into the engine lubrication system, so one is not necessary in the filter. The bypass valve is closed under normal operating conditions. But, if the filter becomes plugged the valve will open and supply unfiltered oil directly to the engine. This will prevent engine damage due to lack of oil flow, but it is not good to have unfiltered oil flowing to the engine, although still much better than the alternative of oil starvation and certain engine failure.

It is very important that you use the oil filter type (not brand) specified by the engine manufacturer as each filter has different bypass valve pressure ratings which correspond to the specific engine it is to be used on.

Advanced Full Synthetic Nanofiber Oil Filters

This is the very latest oil filtration technology. It is patented and only offered by one company, AMSOIL INC. These new oil filters are called EaO, Absolute efficiency Oil Filters and have an incredible nearly perfect filtration efficiency of 98.7% at 15 microns per ISO 4548-12. Typical conventional brand name synthetic blend fiber filters have an 80.23% filtration efficiency at 15 microns and conventional brand name paper oil filters have a 39.39% filtration efficiency at 15 microns per ISO 4548-12.

EAO filters have a far greater capacity than competing filter lines and when used in conjunction with AMSOIL Synthetic Motor Oils in normal service, EaO filters are guaranteed to remain effective for 25,000 miles or one year, whichever comes first. They are guaranteed for 15,000 miles in severe service applications. There is no other company that manufactures and markets and oil filter that meets the EAO's ISO 4548-12 performance or I would also include them on this page.

The EaO filters are manufactured with premium grade full synthetic media under strictly controlled processing which allows them to deliver higher capacity and efficiency along with better durability. Over the service life of a cellulose filter, hot oil will degrade the resins that bind the media. EaO filters' full synthetic media technology uses a wire screen backing that is pleated with the media for superior strength.

EaO Oil filters are constructed with HNBR nitrile gaskets that are fully tested to extreme distances in numerous severe environments. The filters also feature fully tucked seams, a molded element seal, roll-formed threads and a long lasting premium grade silicone anti-drain valve.

By-pass Oil Filtration Systems

By-pass oil filtration systems typically take only a very small percentage of the oil (usually about 10% or less) of the oil flow from the pump. The most common location to tap into to get the oil from is at the oil pressure sending unit by utilizing a special tee fitting. There are several types of by-pass systems but in general the simplest type of by-pass filter systems are the type that have a remote mounted depth type filter on a small valve block. The valve block has metering valves and orifices in it in order to only allow a small portion, usually about 10%, of the oil to flow through it at any given time. The depth type filter is designed in such a way as to "superfilter" the oil and thus it takes longer for the oil to flow through the filter. The filtered oil is returned to either the oil pan, valve cover or filler cap via a special fitting. The hydraulic line used for this type of installation is generally ¼ inch inside diameter.

By-pass systems on heavy diesel engines are installed differently. These engines come from the manufacturer with special ports in the engine block and oil pan specifically for this purpose. Once it is determined which port is pressure and which is for the return oil it is simply a matter of using the proper threaded fittings to adapt to the ports and by-pass system valve block. Some oil pans come with a threaded port for returning filtered oil and some do not. For the engines that do not, there is a port in the side of the block that is used for this purpose. It is best to check with a knowledgeable heavy diesel mechanic, dealership service center or shop manual to determine which port is pressure and which is for filtered oil to return to the block and oil pan. I always check the ports with an oil pressure gage just to be 100% certain which is the pressure and which is return port. The hydraulic lines used for this type of installation do not need to be of large diameter. The typical size is 3/16 or ¼ inch inside diameter.

With both of the by-pass systems describe above, the full flow filter is still retained and utilized. The full flow filter must be changed at the filter manufacturers recommendations. The by-pass filters are generally changed based on the results of oil analysis testing (which is covered in Section 20) or at the by-pass filter manufacturer recommendations. Typical change intervals on by-pass filters are 25,000 miles/1-year for gasoline engine cars and light trucks. Heavy diesel engine by-pass filters are changed in accordance with oil analysis test results or a specific hourly or mileage change interval that is determined by trend analysis (monitoring and testing of used oil over a period of time in order to establish change intervals based on the method in which the particular engine is operated), or the by-pass filter manufacturers recommendations.

Another very popular type of by-pass system is called a Dual Remote filtration system and is the only one of its kind that I am aware of. It is manufactured and patented by AMSOIL INC. The method that this filtration system functions is as follows: a valve block machined to accept a full flow filter and a special by-pass filter is mounted remotely in the engine compartment or under the vehicle, typically on the frame. A special machined or cast aluminum adapter threads on the existing full flow filter location and two hydraulic lines are attached to it and routed to attach to the remote mounted valve block. The full flow filter functions exactly the same as if it were still mounted on the engine, but it is remote mounted and typically in a location where it is much easier to access. The valve block internal orifices and metering valves control the amount of oil that is routed through the by-pass filter, after passing through the full-flow filter. Filtered oil is returned back to the engine adapter via a return hydraulic line exactly as it would be returned to the engine if the full-flow filter were still mounted on the engine. The hydraulic lines used for this type of system are typically 13/32 inch inside diameter because they also have to be large enough to allow for the full flow volume of oil to flow through them. Another benefit of by-pass systems is that oil capacity can be increased significantly, depending on the size of the filters selected.

There are numerous types of by-pass filters and systems on the market. Some examples are Frantz, Lubrifiner, Purifiner and AMSOIL. They vary in terms of cost, function and installation. My personal choice is the AMSOIL by-pass filter. They manufacture both single by-pass units and Dual Remote by-pass units and are the most effective and easy to install systems that I have ever used and their cost is very reasonable when compared to other by-pass systems. They are also extremely easy to service and change filters by simply spinning off the old one and installing the new one.

Lubrifiner also makes an excellent by-pass filtration system however there are installation, cost, serviceability and performance parameters that should be evaluated and weighed prior to purchasing a by-pass filtration system in order to select the optimum system for your specific application. I prefer the AMSOIL by-pass systems due to their unique design, exceptional durability and performance and a system that is available for any type of vehicle from small passenger cars to large heavy diesel engines.

The difference between the AMSOIL By-Pass Filters and others are the unique design of the filtering media and the patented construction of the filter element. The high capacity filtration medium is a special blend of virgin wood and cotton fibers, formed into discs, stacked, and compressed. The center tube is all steel, perforated for oil flow, and wrapped with a fine mesh cotton screen. The by-pass filter will trap dirt particles to 3 microns with almost 100% efficiency and to 1 micron with about 85% efficiency and the medium's fibers can remove up to a pint of water and remove soot (something that no full-flow filter can do). Channeling is eliminated with the inclusion of a hydraulic follower plate activated by a sophisticated internal pressure system. The filter is enclosed in a strong steel canister and threads onto the valve block unit (w).

Note that the diameter of a human hair is approximately 90 microns. This helps to give you a perspective on just how small of particles the AMSOIL by-pass filter can remove. One micron equals 0.000039 inch or 0.001 mm. There is no full flow surface type filter element on the market that can come even remotely close to this type of filtration, which is why by-pass filter systems are so important.

Email author with any questions: dave@performanceoiltechnology.com

18. AIR FILTRATION

Effective air filtration is one of the most important aspects of reducing engine wear. Dust particulates are extremely abrasive and when these particulates are not effectively stopped by the air filter, accelerated rates of engine wear can occur, or in extreme cases immediate internal engine damage can occur.

Dust particles are classified into four major groups according to its particle diameter (b):

- “fine” dust with particles from 1 to 5 microns
- “medium” dust with particles from 5 to 10 microns
- “coarse” dust” with particles from 10 to 50 microns
- “sand” dust with particles from 50 to 250 microns.

To put this all in perspective, a grain of salt has a particle size of approximately 100 microns (0.1mm) and an average human hair has a particle size of approximately 90 microns (0.09mm).

They type and size of dust particulates present in the air depends on which area of the country or world you are in as well as the type of roads you are traveling on and the vehicles ahead of your vehicle which can kick up a lot more dust than normally present. It has been determined that dust particulates present in average air samples is composed of at least 70% silica. Automotive engines should be able to operate effectively in dust-polluted air up to a maximum concentration of 2.5 g/cu meter. Filters on assault tanks or tractors should be able to operate effectively during a long space of time at concentrations between 4 and 8 g/cu meter (b).

In the automotive testing business I am involved with some of the most severe engine dust ingestion testing is performed in Arizona using roads specially prepared with a specific particle size of Arizona test dust and dirt particulates and small pebbles and stones. A vehicle will drive ahead of the test vehicle dragging a special apparatus, which creates an extremely large cloud of dust that the test vehicle drives in. This test is used to evaluate many different parameters from engine wear, air filtration effectiveness, paint chip protection, stone pecking and functionality of underbody parts such as brake and fuel lines and many other parts.

Testing has indicated that piston rings and cylinders are more sensitive than other engine parts to dust ingestion. Maximum wear in the upper cylinder parts appears to occur with particles between 5 and 10 microns (b). This does not mean that it is not important to stop both smaller and larger dust particles. All sizes of dust particles commonly prevalent in the air on the roads we drive on have the potential to cause varying degrees of engine wear and must be stopped from passing through the air filter and entering the engine.

It is extremely important to make sure you that you use a quality air filter and that it is properly installed and sealed at the sides so that dust particles can get past unfiltered. The air filter must be able to both flow sufficient quantities of air for proper engine performance while also stopping damaging dirt and dust particles. A quality paper air filter is effective in stopping most of the dust particles; however there are superior filters on the market with will do a much better job.

Oiled foam air filters are excellent at stopping dirt particles while still allowing for superior air flow. The combination of the thick foam and the honeycomb network of oiled fibers are extremely effective in stopping damaging dust particles. The oil used is a special high tack type which is sprayed on uniformly and allowed to soak into the foam. Typically the filter requires cleaning and re-oiling about once per year or 25,000 miles, whichever comes first, or in cases where more dusty conditions are encountered, twice per year.

In SAE J726 air filter testing this type of oiled foam filter proved to be 99% efficient and could hold 281 grams of dust contaminant (gg). A standard paper element could not come anywhere close to achieving this kind of efficiently and dust/dirt holding capacity nor could an oiled cotton gauze type filter. I have recently seen that some cotton gauze type air filter manufacturers offer an oiled foam wrap or sock element to go over the air filter to act as a pre-filter and increase the dust/dirt stopping ability. If you have this type of filter, I recommend purchasing the foam or sock type pre-filter for additional dirt stopping ability if you operate your vehicles in extremely dusty environments.

Most recently the very latest technology to be introduced is called Nanofiber technology which has been used exclusively in heavy duty applications, including the U.S. Army Abrams M1 tank. AMSOIL INC. has brought this technology to the auto/light truck market, called Ea Air Filters (EaA) which are guaranteed for 4 years/100,000 miles. The nanofiber technology used in the Ea Air Filters surpasses all other technology in efficiency, capacity and service life and is documented by independent laboratory testing performed per ASTM and ISO standards. With Ea Air Filters, dust and submicron particles remain on the surface and are trapped in the nanofibers, preventing particles from lodging in the filter media depth. This produces higher efficiency and higher capacity which extends engine and filter life and reduces engine wear. The Ea Air Filters holds up to 5 times more contaminants than cellulose air filters and 15 times more contaminants than a wet gauze type filter.

Email author with any questions: dave@performanceoiltechnology.com

19. WARRANTIES, MANUFACTURERS BRANDED OIL AND FILTERS AND EXTENDED DRAIN INTERVALS

The purchase of a new vehicle these days is a major investment. Therefore, one of the most important items a person is concerned about both during and after the sale of a new vehicle is what does the manufacturers warranty cover and how long of a time period does coverage last for and what are the conditions of the warranty. Over the years due to the increasing costs of new vehicles, parts and service and the complexity of the vehicles, many people are stuck going to the dealership they purchased the vehicle at for service. This tends to create problems when people want to use non-manufacturer branded or recommended parts, lubricants or filtration products.

Vehicle manufacturers do not refine, blend and manufacture their own oil. What they do is contract with an oil company. Vehicle manufacturers do have certain specifications and requirements that the oil must meet, however “often, the decision as to who actually makes a private labeled product is based on a low bid, and like most everything else manufactured by a low bidder, short cuts are taken in order to make the low price (ee).” “Every manufacturer that makes equipment with an engine has its own name on an oil bottle. You name it, they all have oils, but none of these equipment manufacturers actually make an oil. They sell oil to make more money and often price these oils well above the rate for competitive lubricants because they can create them impression that only their oil be used in their equipment (ee).”

The above statement is supported by test data. One particular company, AMSOIL INC., has "tested a number of these private label motor oils and two cycle oils and has found many are mediocre quality products. None of them even comes close to performing as well as AMSOIL lubricants, and that's a fact (ee)." AMSOIL is one of several oil companies that manufacture superior lubricants to OEM branded lubricants and test their products against specific manufacturer branded lubricants in order to document their claims of superior performance. Tests are initially performed in-house and when the test results will be used for advertising purposes and competitive comparisons the tests are conducted at an accredited independent ASTM test laboratory.

The impression most new vehicles and equipment sales and service personnel often convey to customers is that the customer must use their particular manufacturers brand and viscosity of lubricants (engine, transmission, differentials, etc.) during the warranty period in order to "maintain the warranty" and that the particular lubricants in question must be changed according to manufacturers specified change intervals. I will address this first in respect to the legality and then a practical discussion.

"'Specifically, the legal question posed is whether manufacturers of new vehicles can require that original equipment, parts and services be used in order to maintain a valid new car warranty. It frequently happens that new car representatives will advise the customers that they must use original equipment manufactured parts in order to maintain a valid new car warranty. This happens most frequently when representatives are advising customers regarding motor oil and filters.

Under the Magnuson-Moss Warranty Improvement Act, and pursuant to regulations of the Federal Trade Commission, a manufacturer may not make its vehicle warranty conditioned on the use of any specific brand of motor oil, oil filter, or any other component, unless the manufacturer provides it to the customer free of charge

Very limited exception applies to this, and then only where the Federal Trade Commission is satisfied that the exception is in the public interest. If a manufacturer requires customers to use its motor oil or oil filter, then the customer should demand the products free of charge. There are statutory remedies for untrue statements made by the manufacturers, or its representatives; and if you are a victim of these statements, you may have legal rights to initiate a claim against the manufacturer (cc)"

Therefore, do not let a new car or truck dealership try to tell you that they will void your warranty if you do not use the manufacturers branded products. I have heard accounts of this occurring countless times all across the country. The best defense you can have if it ever happens to you is to be knowledgeable of the laws, as stated above, and firmly let the dealership know that you are aware of these laws and will not be taken advantage of If you reside outside of the U.S., such as Canada for example, these conditions still apply if the manufacturer has an engineering, manufacturing or headquarters/administrative presence in the U.S.

In relation to viscosity and extended drain intervals; you can use any viscosity oil you desire in your vehicles as long as it meets API specifications (and/or ILSAC and GF specs) and classifications **as long as it is correct for the application**. I will discuss practical applications of oil viscosity in section 23.

Vehicle manufacturers recommend lubricants according to their viscosity grade and service classification. Any oil, whether it's conventional petroleum motor oil or synthetic, meeting the correct viscosity grade, may be used without affecting warranty coverage (dd).

In addition, the suspected failure of an oil cannot be a subjective opinion made by dealership personnel. It must be based on the results of documented independent laboratory chemical analysis. If the lab test results indicate the oil is still suitable for continued service, then your warranty cannot be voided, regardless of the length of time the oil has been in service for. If a warranty is ever voided it must be done in writing, not verbally, and there must be substantial and documented evidence as to why the warranty is being voided.

Furthermore, the manufacturer of a non-vehicle manufacturer branded oil may also have a warranty, protecting you even further. I know of one particular manufacturer, AMSOIL INC., which offers synthetic motor oil in many viscosities with a standard drain interval recommendation of 25,000 miles or one year, whichever come first, and a Severe Service 0W-30 synthetic motor oil with a recommended drain interval 35,000 miles or 1 year, whichever comes first, that has their own warranty covering their lubricants and filtration products. AMSOIL also manufactures EAO Absolute Efficiency 25,000 mile/1-year guaranteed change interval oil filters (15,000 miles/1-year under severe service conditions). They state that if a manufacturer warranty is ever voided due to following AMSOIL's recommendations, that the AMSOIL warranty takes effect, but that an oil sample or analysis and inspection of the failed part will be required.

Therefore either way, whether it is with the manufacturer warranty or the particular aftermarket manufacturer warranty, you are covered. Just remember that oil analysis is both very important as a preventative maintenance tool and as a suspected failure analysis tool. I will cover oil analysis testing in section 20. Become an informed consumer and you will most likely be more knowledgeable than the dealership personnel and be able to back up your knowledge with facts and data.

During my career as an Original Equipment Manufacturer Engineer for a major automotive vehicle manufacturer my mode of operation has always been to document my work with data. What I am inferring to by this is that many people such as dealerships sales and service personnel may make statements that they cannot support with data, specifications or documentation. I don't make statements that I cannot support with the proper documentation. If anyone ever questions me, I simply present the data to them.

For example, say I took one of my diesel vehicles in for warranty service. I am using synthetic 15W-40 diesel oil with by-pass filtration. My engine has a manufacturers 100,000 mile/5-year warranty. Now let's say that within the time of the warranty period I was to take it in for a covered engine problem and during the service write up procedure they ask me when my last oil change was and I state that it was 68,611 miles ago. If they try to give me a hard time about this, the first thing that I would do is pull out a copy of my oil analysis report and say "which part of this report states that my oil needs to be changed?" I have the data and the data says that my oil is still perfectly suitable for continued service regardless of what mileage interval it was changed. They must service my vehicle under the terms and warranty.

In summary, if they refuse to honor your warranty then contact an attorney and they will know how to handle it from there. Once you have your facts and data handy and are knowledgeable on consumer protection laws such as the Magnuson-Moss Warranty Improvement Act you it is much more difficult for a dealership service center to take advantage of a consumer.

Email author with any questions: dave@performanceoiltechnology.com

20. OIL ANALYSIS TESTING AND 68,611 MILES WITHOUT AN OIL CHANGE

Oil analysis testing is one of the most effective methods to monitor the oil condition in engines, machinery and equipment. Contrary to popular belief, the color of oil does not indicate its suitability for continued service. Engine oil, for example, is going to turn black over a period of time due to microscopic soot particulates and other contaminants. It is the job of the oil's chemistry and filtration system to properly filter the soot particles within the micron size range capability of the filtration system and chemically neutralize and encapsulate and remaining contaminants and particulates.

Oil analysis testing is the only way to accurately determine the suitability of a particular lubricant for continued service as well as the assessing and monitoring any changes occurring in the engine. Pulling the dipstick and wiping it on a white paper towel means absolutely nothing. That is a common tactic that some service centers may use to show customers that the oil is supposedly "dirty" and needs to be changed. I've seen it all too many times. The customer pulls up to the oil change service bay and the service personnel pop the hood, pull the dipstick and wipe it on a clean white paper towel and show the customer how "dirty" their oil is, which in essence confirms the customers need to have their "dirty" oil changed and also justifies the time and expense to the customer. Black oil on a dipstick is normal and is to be expected. Some oils, engines and filtration systems may keep an oil visually cleaner for a longer period of time, but eventually it is going to turn black.

There are certain exceptions where the condition of the oil on the dipstick may be able to provide an indication if there is something wrong and needs further attention and/or mechanical repair, such as the strong smell of gasoline or the obvious presence of water or glycol, however, this is not normally the case. Oil analysis testing should always be used to accurately determine the condition of an oil.

Used oil analysis has existed as long as lubricants have been around. In the 1940's, the railroad industry began to analyze their lubricants for the various metals found in specific components of the engine. By tracking wear rates and trends from one sample to the next, maintenance could be anticipated and scheduled before component failure resulted in downtime and loss of equipment productivity. This data allowed railroads to schedule teardowns when they were necessary, rather than after a arbitrary number of operating hours. The advent of spectrographic metals analysis gave rise to the practice of "**predictive maintenance"** which continues to be more cost effective than the standard of preventative maintenance (ff).

Today, railroads still use oil analysis as well as many other commercial and industrial businesses such as trucking fleets, logging and excavating companies or any business with heavy diesel or gasoline powered equipment. Oil analysis is not limited only to business and industry; regular motorists also use it extensively.

Oil analysis testing will accurately determine the physical condition of the oil itself based on a number of physical properties such as viscosity, if any solids, glycol, water, and/or fuel are present and if so at which percentages. Oil degradation is measured by the percentages of soot, oxidation, oxides of nitrogen, TBN (Total Base Number) and TAN (Total Acid Number). Note that TAN is typically used for non-crankcase lubricants only.

Oil analysis testing will also acquire data used to predict the condition of the engine or equipment that the sample was analyzed from based on parts per million of certain wear metals. The specific parts per million that is indicated on the data sheets is not most important by itself, but rather by assessing the changes in wear metal parts per million over a period of time and assessing the overall time in service of the particular lubricant and the specific engine and or equipment being tested. Each succeeding report can be compared against the previous one and analyzed in order to determine if anything serious is occurring, or about to occur. This is called trending or trend analysis.

The most common wear metals listed on oil analysis data sheets include iron, chromium, lead, copper, tin, aluminum, nickel, silver, manganese, silicon, boron, sodium, magnesium, calcium, barium, phosphorus, zinc, molybdenum, titanium, vanadium and cadmium. Each wear metal can be correlated to a specific component or area inside an engine, transmission, gearbox, axle or other piece of machinery equipment, based on the metals used in the manufacture in the component.

In engines, the oil analysis can provide information concerning the condition of the air intake system, by monitoring the silicon (dirt) levels in the oil. The levels of iron and aluminum can warn of piston and cylinder wear before a failure occurs. Bearing wear rates can be determined and action taken before the crankshaft becomes badly scored. Fuel dilution, anti-freeze leaks and water entry can be detected while they are still minor problems. The levels of contamination and combustion soot within the oil can indicate a restricted air intake system, ineffective oil filters, poor combustion, or a rich fuel/air ratio (d).

I recently was working on a project with a police department. Their oil analysis samples kept coming back from the lab with high silicon levels in the oil. After continued oil analysis and some additional work it was determined that one of the technicians had replaced the paper air filters with a cotton gauze mesh type of air filter, which had been less effective at trapping silicon particles. The filters were removed, oil changed and new foam filters installed. Subsequent oil analysis reports indicated the silicon levels had significantly decreased. If it were not for oil analysis testing this would have never been detected and the silicon could have potentially contributed to increased internal wear rates.

Several other companies I service have many pieces of heavy diesel equipment which has been operating for thousands of hours without an oil change (using by-pass filtration and synthetic oil) and monitored with regular oil analysis testing, typically every 250-300 hours, or more often if operated in severe dusty environments. Prior to installing by-pass filtration and synthetic oil, oil analysis testing indicated that the oil needed to be changed about every 150-200 hours.

This is just one example of how oil analysis testing, when combined with by-pass filtration and synthetic oil can significantly extend oil change intervals, save money and downtime and most importantly greatly extend the equipment life. This is also why one must look at the overall picture when justifying the higher initial cost of synthetic oil and by-pass filtration. The cost is quickly recovered in time and money savings as well as decreased wear and increased longevity of the engine. Hydraulic systems, transmissions and axles/differentials are also ideally suited to benefit from synthetic oil and oil analysis testing.

Personally, I have detailed documentation from one of my Ford F350 Power Stroke Diesel trucks that has accumulated 68,611 miles (at the time of this initial writing) without an oil change using oil analysis testing combined with by-pass filtration and synthetic oil. This does not mean it it's the same oil since I have regularly changed oil filters and topped off the oil when necessary. It simply means I have not had to do perform a complete drain and refill. I have calculated that over the 68,611 miles, the by-pass system and oil analysis testing has saved me about $2000.00, not including the increased fuel economy and performance improvements realized from the use of synthetic oil, which can be an additional significant cost savings given the high cost of fuel these days. In addition, my engine has less internal wear than a comparable engine that has used only petroleum oil and standard full flow filtration changed every 3000 miles.

Oil analysis sampling is most commonly performed with the use of a special hand pump. The hand pump can be obtained from the oil analysis company that will be performing the lab analysis. A special sample bottle kit is purchased in which the cost of the laboratory analysis testing and final report is included. In some cases postage to the lab is also included with the kit. Note that when using a by-pass filtration system you have the option of adding a special petcock valve to the side of the valve block for oil analysis sampling purposes, or leaving it off and pulling the sample from the dipstick tube using the hand pump. Oil test samples should not be taken from the engine oil filter.

The hand pump typically comes with a length of 3/16 in. diameter tubing. Cut about a 5-6 foot section and carefully push it down the dipstick tube until it reaches the oil pan (make sure to pull your samples just after engine shutdown, when the oil is still warm). Then put the other end of the tube into the top of the hand pump and screw the sampling bottle onto the pump and carefully and slowly stroke the handle back and forth several times until the oil begins to come up the tube and flows into the bottle. Do not rapidly pump the handle it back and forth as it may collapse the sample bottle due to excessive vacuum.

As the level reaches the top simply unscrew the knob where the tube enters the bottle via the hand pump, which will break the vacuum and stop the oil from flowing into the bottle. Carefully unscrew the bottle, cap it tightly, label the bottle and fill out the included data sheet and drop it in the mail. As soon as the lab receives the sample they will analyze it and mail you the results, along with any recommended action required. Some labs are online and will post your results on their website as soon as it is completed. You can obtain a username and password to access your test results online. Note that if the lab detects any major problems that need immediate attention they will typically contact you immediately using the contact information you have provided on the data sheet you filled out.

Note that most larger diesel trucks and even some diesel pickup trucks can use a ¼ inch oil sampling line. The ¼ inch line is readily available in most auto parts and supply stores at a very reasonable price as compared to the 3/16 inch line which is less common and therefore costs slightly more to purchase.

If you need additional information regarding oil analysis testing or interpretation of results please contact me. I have up to date contact information for major national ASTM accredited test labs as well as additional technical information pertaining to analysis information and wear metal analysis.

Email author with any questions: dave@performanceoiltechnology.com

21. GAUGING FUEL ECONOMY IMPROVEMENTS WITH SYNTHETIC OIL

One of the most common questions I get asked is how much fuel economy improvement people can expect to see when they make the change to synthetic oil. I am reluctant to provide any exact numbers because there is no exact percentage increase that will be realized under any given set of operating conditions with different vehicles and vehicle conditions. I can provide a general range of 2 to 8%, for example, or I can state some specific mileage increases that other people have realized or state the results of actual field and fleet tests. **However that does mean that you will see the exact same values, you could see the minimum, average, maximum or even more depending on numerous variables.**

There is documented lab and fleet test data that shows improvements of 4-5% on average better fuel economy with a synthetic 5W-20 vs. 10W-40 and 15W-50 petroleum oils (u) as well as improvements of 8.2% more miles per gallon when synthetics were used in both the engine and drivetrains in a diesel truck test (ii), for example. In order to see exactly what was included in this testing one must review every specific detail involved in the testing. Unless every parameter is replicated it would be next to impossible for you to realize the exact same values that I provided to you, and if you didn't notice those values then you would believe I gave you inaccurate information, however that is not the case when you look all the different parameters that affect fuel economy of any vehicle at any given time.

In my engineering position at a major automotive manufacturer we regularly run fuel economy testing in order to establish the fuel economy numbers that you see on the window stickers new vehicles. These numbers take many hundreds or even thousands of hours of testing using hundreds of vehicles and millions of dollars of equipment and facilities in order to provide an accurate representation of what the customer can expect to see. The U.S. Federal Government also randomly purchases new vehicles all across the country and subjects them to a similar battery of fuel economy certification tests to ensure the numbers are accurately represented by the vehicle manufacturer. Here is an overview of some of the more common parameters are measured, monitored and controlled during testing at the vehicle manufacturer in order to establish fuel economy ratings:

- fuel quality and specific type of fuel, tested and recorded
- barometric pressure
- ambient temperature
- ambient wind velocity and direction
- wheel torque
- exhaust gas temperature
- engine compartment temperature
- manifold vacuum
- inlet air temp and velocity
- air velocity and differential vacuum upstream and downstream of the air filter
- cylinder head temperature

- water (coolant) temperature
- tire type, compound and pressure
- tire evolutions per mile (varies considerably with different brand and type tires of the same dimensions)
- suspension settings, spring rates and options
- fuel flow rate
- fuel pressure
- wind velocity while driving using special instrumentation mounted at several different locations on the vehicle body and underbody
- type and viscosity of lubricants used in the engine, transmission, transaxle and differentials
- test weight of the vehicle, both single passenger, simulated second passenger and/or maximum GVW
- brake caliper drag
- brake rotor lateral runout (LRO)
- brake rotor differential thickness variation (DTV; can generate LRO and brake caliper drag over a period of time)
- brake rotor and lining temperatures
- brake line pressure in each corner of the vehicle
- brake pedal force used to decelerate and stop the vehicle
- parking brake cable loads (possible drag on system) and cage clearances of parking brake linings for drum in hat and drum brake type systems
- axle lube type, viscosity and temperatures
- transmission fluid type and temperatures
- rate of acceleration and loads on pedal
- emissions system performance
- chassis dynamometer testing
- parasitic losses from engine accessories
- external exhaust system and muffler temperatures
- plus many, many more parameters

I could easily continue on and fill up additional pages with the various parameters that all have an effect on fuel economy, however that is not my intent. My intent is only to show you how many different critical parameters all have an effect on overall fuel economy and that any single variable or multiple variable changing can have a significant effect on the overall fuel economy.

Now, lets say that you determine that your vehicle is getting a specific MPG using petroleum oil, and that you believe the value is fairly accurate because you have monitored it over a period of time. Then you change to a synthetic engine oil and on the next tank of fuel determine your fuel mileage has not changed, went down or went up a specific amount. Then you call me and tell me that you changed to a synthetic oil and want to know why, for example, you see your fuel economy has not changed, decreased or not increased as much as you expected. You immediately assume that it was the synthetic oil that caused the change or lack of change. However, can you accurately say that all the other parameters, such as in my list above, have remained exactly the same?

The answer is no you cannot. You have no way of knowing unless you also have the parameters of the critical items in my list identified and measured both before and after.

Unless you have your vehicle completely instrumented to measure these parameters you have no way of knowing, and there are very few, if any, average motorists that have access to such equipment and the knowledge how to use it. **The closest approximation you can do to determine an average value for the specific change you have made is to continue driving your vehicle as you normally do over a significant period of time covering many different ambient temperature and driving conditions and fuelings.**

Even if you say you purchase the same type of fuel from the same station, the facts are that you do not always get the exact same fuel quality or type. Fuel refiners and manufacturers change the blending and percentages of certain key components depending on the time of year, location of the country the fuel will be used at and the specific base the fuel is manufactured from. You have no way of knowing. They fuel may meet a certain minimum RON or MON (Research Octane Number or Motor Octane Number) however there can be different percentages of additives which can easily cause fuel economy to change. This is only one example. There are many more.

My point is that when changing to a synthetic oil you should certainly see some fuel economy increase, and you may see it right away, or you might not. The fact of the matter is that you need to give it thousands of miles over many different driving conditions and seasons and/or weather conditions to **accurately** gage the effect the synthetic had on overall fuel economy, and your vehicle and engine need to be in mechanically good condition. Research and testing clearly indicates that synthetic oil provides improved fuel economy. How much fuel economy varies significantly based on the parameters I have identified.

Additionally, many vehicles PCM's (Powertrain Control Modules) are also programmed based on actual measured data to sample specific values from the many different engine sensors and make changes based on the measured parameters from the various engine and powertrain sensors. Some examples are listed below and are not exactly the same on all vehicles. (Note that I do not intend to go into a detailed description of how each sensor interacts with the PCM and engine operation and how it affects fuel economy):

- AC pressure switch
- Brake lamp switch (informs the vehicle when to disengage the torque converter)
- Camshaft position sensor (tells engine when to fire)
- Clutch pedal position switch
- Intake air temperature sensor (provides info to PCM which uses data to operate the EBP, Exhaust Backpressure Valve, which changes engine RPM while idling
- Transmission control switch
- Vehicle speed sensor (uses the signal to control fuel injection, ignition control, transmission shifting and torque converter clutch scheduling)
- Accelerator pedal sensor, (calculates fuel quantity) for vehicles w/o accelerator cables

- Idle validation switch
- Exhaust backpressure sensor
- Injection control pressure sensor
- Engine oil temperature sensor
- Analog manifold absolute pressure sensor (determines engine load to calculate fuel quantity required)
- Barometric pressure sensor (calculates ignition timing)
- Injector driver module- fuel delivery and timing
- Injector driver module feedback (confirms proper timing/duration of the PCM command)
- Exhaust back pressure regulator
- Injection pressure regulator
- Tachometer output – provides signal to the PCM and is representation of the camshaft position sensor
- Manifold air temperature

These engine sensors have a direct effect on fuel economy and there are also many other variables that go into the PCM calculations. These changes take a period of time to take effect and see the overall result. For example, when changing to a higher flow air filter or a different oil certain sensors have to measure the input values, send the signal to the PCM. The PCM has to determine that these values are different than previous signals and make changes to output signals that control engine operation and fuel delivery. This is an extremely simplified description of the process. In reality it is very complex and beyond the scope of this book.

Scientific data acquired over many years by automotive manufacturers, oil manufacturers and other research and testing facilities clearly show that synthetic oil allows for an increase in fuel economy. In a simplistic description, less resistance to internal drag caused by synthetic oil due to its uniform molecular structure (under extremes of operating temperatures) allows for less fuel input to achieve the same power output. Think of it this way: say you were pulling a heavy load from point A to point B. If you are pulling the load on a rough concrete surface, your body is going to burn more calories to get the load from point A to point B than if you were pulling the load on a surface with a lower coefficient of friction, such as snow or ice. Same exact theory holds true for synthetic oil. It's a proven fact based on physics and engineering tests and data.

Therefore, in summary, when you change to a synthetic oil, or make any other engine, component or vehicle changes you need to allow for the changes to be accurately gauged over a period of time while being aware of all other parameters that have been proven to have an effect on fuel economy.

Email author with any questions: dave@performanceoiltechnology.com

22. SYNTHETIC OIL AND TURBOCHARGERS

Synthetic Oil Proven to Prevent Turbocharger Bearing Seizure

One of the many specific areas on a turbocharged engine that can clearly benefit from the use of synthetic motor oil is the turbocharger. In a typical automotive or diesel engine turbocharger there are two floating bearings lubricated by engine oil tapped from the main oiling system. The job of the oil is to lubricate and cool the turbocharger bearings. These are special bearings usually with internal axial grooves that rotate at extremely high RPM's. Typical turbocharger RPM is between 10,000-15,000 RPM at low engine speed up to around 60,000-100,000 RPM at full engine speed.

When a turbocharged engine is shut off immediately after a high speed run, "heat soak" occurs from the engine, and it considerably increases the temperature in the turbocharger. Over a period of time this can lead to deposits that can block the oil flow to the turbocharger bearings, leading to turbocharger seizure. Synthetic engine oils that are inherently more thermally stable than petroleum engine oils have been shown to keep turbochargers considerably cleaner than petroleum engine oils. A poor petroleum oil will give turbocharger seizure, caused by blocked oil passages, in under 100 hours of a severe "heat soak" test cycle. A good petroleum oil will survive for 100 hours but with considerable deposits and incipient blocking. A good synthetic oil will maintain the turbocharger in almost "as fitted" condition (a).

A very critical aspect of turbochargers in relation to synthetic oil is that it is very important that oil pressures show at the turbo inlet within 2-5 seconds of engine firing (b). This is particularly important under cold starting conditions. If a turbocharger runs at high RPM's for more than several minutes before oil reaches it, turbocharger failure is imminent after a short period of these types of starts and operation. Designers are careful to ensure that oil passageways to turbochargers are of a large enough diameter so as to not impede the flow of cold viscous oil. This is just one of many areas where a premium quality synthetic oil will drastically outperform a petroleum based oil. Typical pour points for premium quality synthetic motor oils range from minus 44 to minus 60 deg. F. At those temperatures petroleum oil will be extremely viscous and very difficult to pump until it warms up.

In addition, when the engine and turbocharger are operating at maximum engine RPM and temperature a premium quality synthetic oil will provide for significantly improved cooling and heat transfer of the turbocharger unit and bearings as well as superior resistance to heat degradation of the oil. This will help to prolong the life of the turbocharger unit. It is also important not to shut a turbocharged engine off immediately after operation because the turbocharger needs to have oil flowing through it in order to cool it. Idle the engine for approximately 3-4 minutes for normal use up to 8-10 minutes after severe use. In my turbocharged diesel vehicles I use thermocouples in the turbo exhaust outlets in order to monitor exhaust gas temperatures and I also have an automatic idling and shut down system installed so I don't have to sit there and wait in the vehicle. Email author with any questions: dave@performanceoiltechnology.com

23. THE DIFFERENCES BETWEEN 0W-30, 5W-30 AND 10W-30 MOTOR OILS

0W-30, 5W-30 and 10W-30 synthetic motor oils are all 30 weight oils. Any one can be used regardless if your vehicle owner's manual says to use, for example, a 5W-30. "W" means winter. In winter weather the 0W oil will flow like a 0W oil, and the 5W will flow like a 5W oil and a 10W will flow like a 10W oil just until the engine warms up. In order to understand the differences one has to first understand that **the numerical values given to these various weight oils are strictly empirical numbers.** For example, 0W does not mean that the oil has no weight. That is one of the reasons why I say it is strictly an empirical number. It could have been called anything the oil manufacturer wanted to call it. The 0W typically denotes an oil with a lower kinematic viscosity for cold weather starting and operation, however that does not in any way mean that it is limited to only cold weather applications.

In order to determine the differences between the three oils one has to look at the **kinematic viscosity** of each lubricant. The kinematic viscosity is essentially the amount of time, in centistokes, that it takes for a specified volume of the lubricant to flow through a fixed diameter orifice at a given temperature.

<u>Let's compare the kinematic viscosity of the three premium quality synthetic lubricants:</u>

0W-30 is 57.3 cST @ 40 deg. C, & 11.3 cST @ 100 deg. C

5W-30 is 59.5 cST @ 40 deg. C, & 11.7 cST @ 100 deg. C

10W-30 is 66.1 cST @ 40 deg. C, & 11.7 cST @ 100 deg. C.

As you can see from the data above the kinematic viscosities are extremely close. Therefore, whether you use the 0W-30, 5W-30 or the 10W-30 is strictly a matter of choice. With the small differences in kinematic viscosity you would be hard-pressed to detect these differences on initial engine start-up without specialized engine test equipment.

All three oils are excellent motor oils and ANY one can be used in a vehicle that requires either a 0W-30, 5W-30 or 10W-30 oil as well as in several other engine applications including an engine which recommends a 5W- 20 oil.

One particular company, AMSOIL INC., engineers and manufactures a premium quality Series 2000 0W-30 Severe Service motor oil that is one of the absolute best synthetic lubricants for gasoline engine passenger vehicles and light trucks on the market. The molecular and chemical technology used to develop this oil was derived from racing oil formulations. It is a 35,000 mile/1-year motor oil. This is the same oil used by numerous police vehicles and severe duty fleets nationwide. I know of absolutely no other oil manufacturer that recommends and guarantees 35,000 miles/1-year change intervals with any of their oils. In fact, many racing teams use the 0W-30 Severe Service. The extra horsepower, torque and internal engine friction reduction from the 0W-30 often assists a race driver in attaining faster lap times and a better starting position. Other racing teams that use alcohol or nitro-methane fueled engines prefer the 20W-50 Racing Oil or the SAE 60W Racing Oil which reduces the thinning effects of fuel dilution on the oil.

This leads to the next topic: **many people also ask me if 0W-30 (or any 30-weight oil) is too thin of a viscosity oil for high ambient temperature operation or severe duty use.** The answer is absolutely not. Thicker viscosity oils are not always necessarily better since in addition to its' various engine lubrication functions; an oil must also effectively transfer heat. Only about 60% of an engines cooling is performed by the engine coolant, and only on the upper half of the engine. The remaining 40% of an engines cooling is performed primarily by the engine oil.

Additionally, it is also the base stock formulation and the particular additive chemistry of the oil that determines the shear strength and performance. It is inaccurate to assume that lighter viscosity oils provide less protection. As I have previously stated in other sections of this book, review the specification and data sheets of the particular oil you are considering to use and compare it with the specifications and data of your current oil or other oils you are considering to use. That will provide for a much better indication of the performance of the particular oil.

Although a vehicle that is recommended to use a 30-weight oil can also use a 40 weight oil, it is usually not needed. You will gain absolutely no benefit from using a thicker viscosity oil if it is not needed. In general I will recommend a 10W-40 weight oil for a passenger car or light truck application is if the vehicle's engine has more wear than is considered normal and if it consumes oil at a higher than normal rate or if the vehicle is being used for very severe duty, high load, high temperature applications such as towing or heavy duty RV use.

I’ve also run across many people that live in hot weather climates that either think they should be using a 20W-50 in their engine, or someone told them that’s what they should be using. It is a common misconception. Thicker does not always mean better, and certainly not with the cars and light trucks being produced today. Modern day passenger cars and light trucks do not need to be using a 20W-50 unless specific conditions require it. Conditions that may require a 20W-50 oil are typically very severe duty truck or RV use and diesel or racing applications in high ambient temperature operation. Even many high horsepower racing engines may not always use a 20W-50. Some use a 0W-30, 5W-30 or 10W-30, to gain the competitive edge by reducing internal drag, which provides for increased horsepower and torque.

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24. CONVERTING TO SYNTHETIC MOTOR OIL, BREAK-IN AND THE MYTH OF SYNTHETIC MOTOR OILS AND LEAKS

Some of the most frequent questions I am asked about synthetic motor oils are, what is required in order to convert to synthetic oil, how long do I have to wait before installing synthetic oil in a new engine, and what can I expect to notice once converted to synthetic oil.

Converting a vehicle to synthetic motor oil is simple, however there are a few things you need to be aware of. First, if you have a new vehicle I recommend that you run a short cycle (typically 500-100 miles or to your first scheduled oil change; whichever you choose) of the manufacturers factory fill petroleum oil on a gas engine passenger car or light truck (on diesel truck engines this value is typically longer and is usually stated in the owner’s manual by the manufacturer of the vehicle and/or engine).

This doesn't mean that you can't install synthetic oil sooner (there are some manufacturers that install synthetic oil as a factory fill) it simply means these are my recommendations based on my extensive engineering work and knowledge of this topic as well as the practicality aspect of it. It doesn’t take long to rack up 500-1000 miles on a vehicle. If you don’t want to run the petroleum oil for 500-1000 miles you can drain it sooner and change to synthetic oil or you can continue to run the factory fill oil to the first scheduled oil change. It is not as big an issue as some people make it seem to be. **The 500-1000 mile figure is very general. There is no set cast in stone mileage recommendation that you must or must not convert to synthetic oil at. Synthetic oil will not prevent your engine from properly wearing in, contrary to what many people believe.**

For example, some synthetic oil manufacturer’s publish recommendations on when an engine can be converted to synthetic oil. Here are AMSOIL INC’s recommendations:

“Regarding the use of AMSOIL Synthetic Motor Oils in brand new or rebuilt engines, AMSOIL synthetic motor oil can be used during break-in trouble free. In fact, vehicles such as the Dodge Viper, Chevrolet Corvette, all BMW vehicles, all Porsche vehicles, Mercedez Benz, 4 Cadillac models, Pontiac GTO, Harley Davidson Screamin Eagle motorcycles and many others come factory filled with synthetic oil. However, since most new vehicles come filled with petroleum oil, it only makes good sense to change to AMSOIL at the first scheduled oil change interval. New engine components generate high levels of wear metals and can contain contaminants from assembly. By allowing the engine to operate with the petroleum oil until the first oil/filter change interval, the wear metals and contaminants are removed prior to installing AMSOIL. There are a couple primary reasons for this recommendation.

1. New engines or engine components generate high wear metals to begin with and generally contain debris from machining and assembly. It is more beneficial to allow these wear metals to collect in an inexpensive motor oil than to circulate throughout the crankcase for extended periods in a synthetic motor oil. By operating the vehicle to its first drain interval with a petroleum oil, these wear metals and manufacturing debris

collect in the oil and are then flushed out of the crankcase when drained. This allows for a much cleaner operating environment for the synthetic lubricant.

2. Within the first miles of operation, if there are any defects in the assembly or workmanship of the engine components, then they may be corrected before installing the more expensive synthetic motor oil. Occasionally, rebuilt engines may have re-machined components or materials which can sometimes be mismatched. These problems will develop in a fairly short period of time. If excessive oil consumption or any other problem is noted, this should be corrected prior to changing to AMSOIL Synthetic Oil.

For racing applications, a synthetic motor oil can be installed right away. These engines are frequently disassembled and rebuilt under more exacting conditions and require the improved wear protection of a synthetic motor oil. Extended drains are rare due to contaminants such as fuel dilution and dirt entry are common, therefore we would recommend oil analysis to determine serviceability of the lubricant."

Today's modern engine designs and manufacturing and materials technology is much more sophisticated than in years past. Regular gas engine passenger car and light truck engines do not require the extensive break in process many people think they do. In addition, by the time you get your new vehicle the engine has already been through a series of hot tests also run on in-plant chassis rolls testers to check functionality of all systems and then driven around the plant and railhead in order to get the vehicle to the dealer, which also helps accelerate breaking in of the engine.

The engine break-in issue is the subject of much controversy, as everyone seems to have an opinion on when an engine is considered fully broken in, yet they rarely have any documentation or facts supporting their opinion. The information I provide is based on the results of engineering work as well as many years of experience and teardown analysis on test engines from all types of vehicles and equipment. The differences between an engine that is fully broken in and one that is not can be extremely difficult to detect except in all but the most extreme situations by an experienced engineer with instrumentation and there is no consumer in a production car or light truck that would ever be able to tell the difference. The subject of tribological concepts of wear and review of the data can be the subject of separate book therefore what I cover in this book is only the essential points you need to know.

The meaning of breaking in an engine is a process of wearing-in the pistons/cylinders/rings, bearings, valves, camshaft, lifters, rockers, etc. In addition, part of the breaking in process is not only wearing-in and seating the internal engine components but also stress relieving the components as well. Crankshafts, connecting rods, pistons, blocks etc. have many stresses due to the casting or forging process and the machining and welding process. I have viewed and measured these stresses, called fringes, using what is called laser holography.

These stresses are properly reduced/eliminated by costly and time consuming heat aging as well as shot peening and/or high frequency vibration on a very specialized bedplate for an extended period of time. For production applications this is cost and time prohibitive. Therefore, the next best thing is exposing your engine to multiple heating and cooling cycles under various load and RPM's, which is described in the following paragraph. **The heating and cooling break in process continues over a period of time and does not need to be run on petroleum oil.**

My general recommendations are to run the factory installed petroleum oil for about the about the first 500-1000 miles, or your first scheduled oil change; whichever you choose. Then drain the oil, remove the factory installed oil filter and then install a premium quality synthetic motor oil and a premium quality oil filter and your ready to go. Again, I want to make it clear that synthetic oil will not prevent your engine from properly wearing in and you most certainly can convert to synthetic oil sooner than 500 miles if you desire.

Further heat cycling break-in will continue during the multiple heating and cooling cycles from driving your vehicle under varying RPM and engine load conditions and by shutting it down for a period of time to let it cool. The multiple heating and cooling cycles are an important and often overlooked factor in the break in process. These heating and cooling cycles achieve what is called stress relieving. Back in the "old days" of engine manufacturing, after casting and before an engine block was machined, it would be set outside for several months to age, during which stress relieving occurred naturally, then the block was machined, which helped to produce a better engine than one that was machined immediately after casting.

By changing the factory installed oil and filter around the first 500-1000 miles, or the first scheduled oil change, you will also be removing the initial wear-in particulates present in the oil and filter. The reason for this is that during initial wear-in there is very high particulate contamination in the oil. These particulates consist mainly of microscopic particles of aluminum, chromium, copper, tin, bronze, lead and iron, plus soot particles and other by-products of combustion in your oil.

The oil filter cannot filter out all these small particulates since many are sub-micron size and too small for the filter to trap, but they are also small enough to fit between bearings and other internal clearances and potentially cause wear. That is why I recommend to that in order to properly wear-in a new engine perform the first oil and filter change at about 500-1000 miles, or the first scheduled oil change, whichever you prefer and feel comfortable with. Personally, I convert my new vehicles and equipment to synthetic as soon as possible, within the first 500-1000 miles, or at about 25-50 hours on tractors and certain equipment operated by the hour in order to achieve the benefits of the synthetic oil without waiting for my first scheduled oil change. Small engines such as lawn and garden equipment, generators and power washers can be changed over sooner.

Flushing The Engine

In a new engine with low miles (up to about the 15,000 mile range) it is not imperative that engine flush be used, although I still recommend it. In an engine with more than

15,000 miles, that has been using petroleum oil the entire time; I highly recommend using the AMSOIL engine flush. What the AMSOIL engine flush will do is remove the petroleum oil sludge and varnish deposits from your engine and properly prepare your engine for synthetic motor oil. You simply pour in one can (16 ounces) for every 5 quarts of sump capacity (one can is sufficient for most all passenger cars & light trucks, with the exception of diesels), and let the engine idle for about 15-20 minutes then drain the oil and remove the filter while the oil is still warm. Do not drive the vehicle with the engine flush installed.

If you have an extremely contaminated or high mileage engine then I recommend installing a new engine oil filter prior to adding the flush so that you have full capacity of the filter available for capturing and holding the dirt particles that the flush removes. Not all engine flushes are created equal. I personally use and recommend AMSOIL Engine Flush. It is a detergent based flush with some kerosene and other petroleum distillates that act as the carrier for the flushing and cleaning agents. The detergent used is a 2-butoxyethanol, glycol ether and is essentially a very concentrated form of the detergents used in the motor oil.

What happens when you operate an engine on petroleum oil is that the sludge and varnish deposits that occur as a result of using petroleum oil will accumulate around your pistons, rings, seals, valve train and other internal engine components and actually help to seal your engine. This type of petroleum oil deposit "sealing" can lead to problems such as piston ring sticking, sludge deposits in valve covers and oil pans which can lead to decreased oil pump capacity output and restriction of critical oil galley passageways over an extended period of time, plus many more issues which I will not go into detail in this book. These deposits are detrimental to the proper operation and longevity of your engine.

What occurs during engine use over a period of time is that synthetic motor oils, due to their natural cleansing properties and high detergency, will clean sludge and varnish deposits out from your engine, both the highly accumulated deposits as well as the sub-micron deposits which have accumulated in the microscopic valleys of the aluminum, copper, iron, etc. engine components. Therefore, if you do not use the engine flush a premium quality synthetic motor oil will do essentially the same thing the flush does but take a longer period of time and could possibly necessitate a filter change sooner than normal.

During this time, which is greatly accelerated when using engine flush, the engine is going through a phase where these deposits are being removed, or have been removed. What exists now is that these microscopic valleys in the iron, aluminum, copper, etc, are now empty. It takes some time for the molecular structure of the synthetic motor oil to fill these microscopic valleys. This can be as short as a few hundred miles or as long as a few thousand miles, depending on the internal condition of your engine. During this phase you may, or may not, notice slightly increased oil consumption but only until the uniform molecular structure of the synthetic motor oil can re-seal these microscopic valleys. Most people do not even notice this phase, but I like to make people aware of it so they understand this process. This is perfectly normal and the oil is doing exactly what it was engineered to do. Additionally, synthetic oil is much less volatile than petroleum oil, which will result in reduced oil consumption.

Synthetic Lubricants, Seals and Leaks

You may have heard the myth that synthetics cause engine seals to leak. Synthetics absolutely **do not cause seals to leak**, they simply may only possibly **reveal an existing leak path** and a seal that has failed and is in need of mechanical replacement. Either the seal lip is worn down or the seal is hardened and cracked from old age, heat and ozone. If you have an older higher mileage engine that has been running petroleum oil for its entire life, and it also leaks, for example around the rear-main oil seal, then chances are it may leak the same or possibly more with synthetic oil. Synthetic oil is naturally cleansing and high detergent and will remove internal engine sludge and varnish deposits, but synthetic oil does not cause leaks. This is commonly referred to as a false seal.

Synthetic motor oils are recommended for use in mechanically sound engines. If you have an engine that leaks oil excessively, then repair the seal prior to converting to synthetic oil. The sludge and varnish accumulation inside an engine is highly detrimental to its proper function and longevity and the miniscule "benefit" you may get from it helping to seal a faulty seal does absolutely nothing for your engine. If you have an older engine with a faulty seal and don't want to change the seal but still want to use synthetic motor oil, then I recommend a higher viscosity, such as a 10W-40 instead of a 30-weight oil.

Email author with any questions: dave@performanceoiltechnology.com

25. 5W-20 MOTOR OILS

Recently several automotive manufacturers started using 5W-20 or 0W-20 motor oil as a factory fill. Most consumers have many questions about this "new" oil and why after all these years specifying a 5W-30 that they would make the change to 5W-20 or 0W-20. First I must explain that 5W-20 (or 0W-20) is not a new viscosity motor. 5W-20 has been around since the early 1970's, but not used by consumers or marketed to consumers by manufacturers, until recently.

My research has uncovered the following from a SAE technical paper written by Mobil Research and Development Corp. in 1975 (o): "Research Oil 5 (RO-5) is a conventional 5W-20 viscosity mineral oil product containing an API SE quality additive treatment, but that it may be deficient in some API SE engine performance requirements. RO-6 is also a 5W-20 viscosity and API quality SE but utilizes all-ester (synthetic) base stock components. Adequate wear protection with conventional 5W-20 viscosity mineral oils has been difficult to achieve under moderate and high temperature operating conditions." Mobil's new 5W-20 synthetic formulation, XRN 1669 "has been evaluated in both laboratory and field tests to determine its antiwear performance. In all cases, wear protection equal to or better than premium API SE quality SAE 10W-40 mineral oils has been provided by this experimental formulation"

Now, keep in mind that this is from about 30+ years ago. My intent here is to show that 5W-20 is not a new viscosity of oil. It just never became widely used. The most popular motor oils back in that era for automotive use were typically 10W-40 and in later years 10W-30 and 5W-30. What this data indicated is that a 5W-20 petroleum oil provides adequate engine protection under normal operating conditions, but does not compare to a premium quality 5W-20 synthetic in moderate and high temperature operating conditions. The new 5W-20 oils of today are formulated to meet the latest API SL performance specifications and are perfectly suitable for use in your new vehicle that specifies 5W-20, however my personal opinion is that there are superior oils to use that not only meet the 5W-20 performance specifications, but also exceed them.

Here is a brief discussion of some of the most common questions consumers have regarding the 5W-20 motor oil that is specified for their new vehicle.

Question: Do I really need to use 5W-20 or 0W-20 oil?

Answer: You certainly can if you choose to, however there are also other viscosities you can use such as 5W-30 and 0W-30 that also meet manufacturers and API specifications. One of the main reasons 5W-20 or 0W-20 was specified for your engine is to increase the CAFE (Corporate Average Fuel Economy) reported to the Federal Government. CAFE is the combined average fuel economy of all of a vehicle manufacturers product line. Minimum CAFE levels are specified by the Federal Government. In order for a vehicle manufacturer to continue selling profitable large trucks and SUV's, which typically have poor fuel mileage ratings, as compared to smaller cars, and still meet mandated CAFE requirements, they must also sell enough of the smaller cars which have much better fuel economy ratings to offset the poor fuel economy ratings of the larger vehicles. The change to a 5W-20 or 0W-20 oil will allow a manufacturers overall CAFE to increase by a very small amount, typically in the tenths of a mile per gallon range. 5W-20 and 0W-20 oil is a lighter viscosity than a 5W-30 oil and therefore has less internal engine frictional losses, or less drag on the crankshaft, pistons and valve train, which in turn promotes increased fuel economy. This increased fuel economy is virtually undetectable to the average motorist without the use of specialized engine monitoring and testing equipment under strictly controlled test track driving when compared to a 5W-30, 10W-30 or a 0W-30 viscosity motor oil. Note that certain specific vehicles, such as those with cylinders that selectively cut out to save energy, typically specify a 5W-20 or 0W-20 and for those vehicles it is best to use the viscosity recommended by the manufacturer.

Question: Could using a 5W-30, 10W-30, 0W-30 or even a 10W-40, oil in my vehicle which recommends a 5W-20 oil void my new car warranty?

Answer: Vehicle manufacturers recommend using motor oils meeting certain viscosity grades and American Petroleum Institute service requirements. Whether a motor oil is a 0W-20, 5W-20, 0W-30, 5W-30, 10W-30 or 10W-40 or even a synthetic vs. a petroleum based oil will not affect warranty coverage. The manufacturer is required by Federal Law to cover all equipment failures it would normally cover as long as the oil meets API service requirements and specifications and was not the cause of failure. In addition, the Federally mandated Magnuson - Moss Act states that a manufacturer may not require a specific brand or type of aftermarket product unless it is provided free of charge. If your dealership continues to tell you that you must use 5W-20 or 0W-20 motor oil and or/ a specific brand of 5W-20 or 0W-20 motor oil (and will not provide it free of charge), then ask them to put it in writing and then contact an attorney. Their position is inaccurate, and, in fact violates existing law.

Additionally, if there is ever a question of whether or not a particular motor oil was the cause of an engine failure make sure to get a sample of the used oil in a clean bottle, typically 6 oz. minimum. The oil can then be sent to an independent ASTM certified testing lab for analysis. This is standard procedure for most commercial vehicles, trucking, construction/excavation and fleet companies and there are many certified test labs all over the country. Remember, a knowledgeable and informed consumer is your best defense against being taken advantage of by a car dealership service center.

Question: My car dealership service center states that I must use 5W-20 or 0W-20 because the oil passages inside my engine are smaller and a higher viscosity oil will not properly flow through them. Is this a true statement?

Answer: That is ridiculous to assume that a manufacturer would purposely make the oil galleys and passages smaller. There is no technical or cost/performance benefit to doing this in reference to recommending a 20W motor oil over a 30W motor oil. My inspection of oil galleys, pistons, bearings, crankshafts, oil pumps and passages from pre-5W-20 and 0W-20 recommended oil engines to the same size and brand of engines that now specify

5W-20 or 0W-20 indicate there are no measurable differences in the oil passages in these components.

For those consumers that desire to use a 5W-20 oil, AMSOIL INC., does manufacture an excellent extended drain interval 5W-20 synthetic motor oil, called XL Synthetic Oil in 5W-20 viscosity. It is a 7,500 mile/6-month motor oil (or longer if you have an electronic oil life monitoring system). AMSOIL's 5W-20 synthetic motor oil provides outstanding wear protection and increased power, performance and fuel economy in high and low temperatures and also meets and exceeds the manufacturer's specifications.

My recommendation is for even better performance and protection to use AMSOIL's Series 2000 0W-30 synthetic motor oil. This is the top performing AMSOIL Synthetic Motor Oil for gasoline powered light trucks and passenger cars. It uses race-proven technology and provides unsurpassed fuel efficiency and superior wear protection than other conventional and synthetic motor oils. It is a 35,000 mile/1-year change interval motor oil. Use it in conjunction with AMSOIL's Absolute Efficiency Oil Filter's that specifies a change interval of 25,000 miles/1-year, whichever comes first under normal service conditions. AMSOIL also offers 5W-30. 10W-30 and 10W-40 Synthetic Motor Oils with a change interval specification of 25,000 miles/1-year.

Email author with any questions: dave@performanceoiltechnology.com

26. ARE 3000-MILE OIL CHANGES REALLY NECESSARY? SYNTHETIC VS. PETROLEUM OIL

If you're like most people you have been brought up being taught that it is necessary to change your oil every 3000 miles. Many people that have been doing this since they first started driving and believe they are doing the right thing because that is what many automotive manufacturers recommend (depending on the severity of operating conditions) as well as the constant bombardment of TV, radio and magazine and newspaper advertising from the major petroleum oil manufacturers. With all that "positive" reinforcement I can see why it's easy to think that 3000 miles oil changes are required and considered normal.

That is far from the case and is also one of the reasons why I waited to the latter part of this book to discuss this controversial topic. I wanted you to have a solid understanding of what is covered in the preceding sections of this book so you have a basis for the facts disputing the validity of the 3000-mile oil change and supporting extended drain intervals with premium quality synthetic motor oil. Based on what you have read in the previous sections of this book you should easily be able to formulate your own conclusions supported by the engineering and scientific/chemistry facts presented.

When looked at from an engineering and chemistry standpoint there is absolutely no way an arbitrary number such as 3000 miles can be recommended and specified for all cars and light trucks. That's why I say the 3000-mile oil change is more of a marketing program headed up by the major oil and quick lube companies fighting to retain the 3000-mile oil change.

Every year in the U.S., this too-short drain interval results in the unneeded production of 300-400 million gallons of engine oil; excess consumer expenditures of around $1.5 billion; and tens of millions of unnecessary oil changes, not to mention the millions of gallons of waste oil improperly disposed of (qq). For about the last 30+ years petroleum oil companies have recommended 2000-3000 miles oil changes in spite of the drastic increases in engine and lubrication technology. In the last decade alone the U.S. oil classification system has produced five major upgrades with more coming in the future. Despite these quality improvements there has been no meaningful improvement in the U.S. average gasoline engine drain interval (rr).

Recently, owners of Mercedes-Benz vehicles received a $32 million class-action settlement by a U.S. District Court Judge in Philadelphia for the company's failure to specify the use of synthetic motor oils with its Flexible Service System (FSS). Through the FSS motorists extended their drain intervals from 12,000 up to 20,000 miles using petroleum oil, as specified in their owners manual. The problem was that petroleum oil could not maintain protection or performance throughout the extended drain intervals. At no time during the case did Mercedes-Benz dispute that the drain intervals were too long for conventional oils, however Mercedes-Benz felt that the case was not that big of a problem and did not warrant a class-action suit (ss).

There are wide variances in the quality and additive package of motor oils and wide variances in vehicle operating conditions. Certainly an average quality petroleum oil can require changing at 3000 miles because the base oil and additive package is also average, however a premium quality petroleum oil with a superior additive package can be suitable for continued service for longer than 3000 miles. The oil and air filtration system, as covered in Sections 16-18 of this book, are also very important to the suitability of any motor oil for continued service. Properly formulated premium quality synthetic lubricants are also capable of extended drain intervals far beyond 3000 miles.

As I have stated previously and will restate again because of its critical importance the only way to accurately determine the suitability of any motor oil, including “3000-mile oil”, for continued service is to perform oil analysis testing. Based on the results of laboratory chemical trend analysis of your particular motor oil used in your vehicles and operating under your driving conditions it is easily determined as to what the change interval should be. It certainly is not going to be 3000 miles for everybody and in many cases can be well beyond 3000 miles, even with petroleum oil.

Now, normal average everyday drivers are not likely to go to these extents to determine when their motor oil needs changing so they tend to go for the 3000-mile oil change. They pull into the quick lube and pop the hood, while the service tech pulls the dipstick out, wipes it on a clean cloth and goes to the window of the driver and shows them their black “dirty oil”. This is a common practice I have seen used many times. They know very little, if anything at all, about oil analysis testing and do not utilize oil analysis testing in determining drain interval requirements.

I’ve seen them do the same thing with certain synthetic oils also. The customer is charged more money for the added protection and performance of the synthetic, but told to come back to change it sooner than is necessary. Statistics show that most customers do not come back in 3000 miles. Some do consistently but others stretch it out to the 4000-mile range, or higher, for both petroleum oil and synthetic oil. The quick lubes attempt to do their best to convince customers that they should come back in 3000 miles, however many just do not for a variety of reasons from busy schedules to stretching their dollars by traveling beyond 3000 miles on the oil. It makes sense as a business owner that if they can see their customers more often they can make more money. I attempt to show quick lube operators how they can charge more money for a premium quality extended drain interval synthetic, see their regular customers less often, and free up their service bays so they can see more new customers. This is a win/win situation for both the business owner and the customer.

In a recent interview the president of one of the largest quick lube chains, owned by a major oil company, stated if they can get customers to shorten their drain intervals by 100 miles it would mean an additional $20 million in revenue for the company per year and if they can get consumers to do one more oil change per year it would mean $294 million for the oil change alone and $441 million in revenue when they include ancillary products and services that go along with the oil change. In fact, he openly admits that the bottom line is profits. The shorter the drain interval, the more money for the quick lube chain and parent company (mm).

Many of these quick lubes and petroleum oil companies attempt to debunk extending drain intervals with a premium quality synthetic based on information which does not pertain to synthetic oils. Such information includes that the additive package wears out and that the oil becomes contaminated with the by-products of combustion, which necessitate frequent oil changes.

The notion that synthetics cannot extend drain intervals because the additives wear out as they do in conventional oil is a myth. Additives last longer in synthetic lubricants. It is documented through analysis that this is the truth. Let me say it again: extended drain intervals with synthetics are a reality and additive packages last longer in synthetic oil. There are facts (oo).

With regard to the by-products of combustion, it is also a fact that engines run cleaner with synthetic lubricants. Unlike petroleum, the by-products of combustion do not hinder the ability of synthetic lubricants to provide protection during extended drain intervals. The limitations of petroleum based oil, and the two problems cited are the primary reasons why oil companies appear so adamant about the 3000-mile drain interval requirement. Neither one of these reasons interfere with the ability of properly formulated synthetics to provide service for extended drains (oo).

It is also important to note that in Europe manufacturers recommend significantly longer drain intervals using synthetic lubricants as well as with petroleum oils. In fact, Europe's target is to achieve 20,000-30,000-mile oil change intervals with synthetic lubricants in the near future. Many manufacturers are also beginning to recommend extended drain intervals in the U.S, well beyond 3000 miles, but still not approaching where Europe is at. These differences in oil change interval recommendations cannot be explained by superior engineering of the European vehicles. There may be significant cost, quality and performance differences between the European vehicles and U.S. vehicles but the fact still remains that they are both internal combustion engines operating on the same engineering principles with similar engine designs and materials.

Synthetic lubricants will provide for improved wear protection under all operating conditions and especially under high and low temperature extremes. Synthetics will provide for immediate start-up wear protection and faster warm-up wear protection that a petroleum oil simply cannot come close to providing.

Synthetic lubricants will also provide for improved deposit control such as reduced piston deposits, intake valve deposits, turbocharger deposits, combustion chamber deposits and oil system deposits such as sludge and varnish.

Synthetic lubricants have also been proven to provide for improved fuel economy and energy conservation as well as reduced oil consumption and extended engine life as well as maintaining the engine at peak performance, which assists in reducing emissions.

Extended drain intervals also reduces the quantity of oil used and the quantity of used oil that must be disposed of.

Many people are scared away by the high cost of synthetic lubricants. However, this is simply not the case when the facts are numbers are reviewed. With fuel prices hovering around $2.50-$3.00 per gallon nationwide, consumers are searching for methods to save money without a major investment in a smaller more fuel efficient vehicle. The major oil companies are pulling in huge profits, yet I have not seen them aggressively promoting synthetic oil and the major fuel economy savings that it can provide. For example, AMSOIL has 34 years experience of producing the world's finest PAO-based synthetic motor oil and has countless testimonials and documented tests that show fuel savings of 3-5%, up to 8-10% or more in some cases.

Some people say AMSOIL is expensive. I say it's free:

Here's why: Say you pay $29.95 to get your oil changed every 3,000 miles. That's 8 oil changes to travel 24,000 miles at a cost of $239.60, not including your time, for 8 trips to the quick lube. If you change it yourself at a cost of $20.00 per change for the oil/filter, then your total cost is $160.00.

Now, do it yourself using AMSOIL's 5W-30 or 10W-30 25,000-mile/1-year oil at a retail cost of $6.15 per quart times 8 quarts (enough oil for the initial change, and enough to add as it is used during the course of the 25,000 miles) plus one AMSOIL Absolute Efficiency 25,000-mile/1-year oil filter at a cost of $10.00. Your total cost is $49.20 plus $10.00 = $59.20.

AMSOIL saves you $180.40 over the quick lube cost and $100.80 over the do-it-yourself cost on the oil and filter change alone. Additionally, if you drive 25,000 miles per year and get an average of 17 MPG, you would use 1,470 gallons of fuel per year. With an average conservative estimate of 5% fuel economy improvement with AMSOIL you would now only use 1,396.50 gallons of fuel per year, which saves you 73.50 gallons of fuel per year times $2.70 per gallon = $198.45 fuel savings.

With AMSOIL, your total savings now increase to $378.85 over the quick lube cost and $299.25 over the do-it-yourself cost. Therefore, AMSOIL pays for itself and saves you time.

Even if you don't drive 25,000 miles in a year and do less than 8 oil changes per year, you're still saving money. You save even more money by purchasing AMSOIL at wholesale prices. This generally will save you an additional 25% or more off the cost of the oil and filters.

With savings like this, how can you afford not to use AMSOIL?

If you drive more than 25,000 miles in a year, AMSOIL also manufactures a Series 2000 0W-30 Severe Service synthetic motor oil which is a 35,000-mile/1-year oil and a Series

3000 5W-30 HDD which is a 25,000-mile/1-year oil in gas and diesel engine vehicles. AMSOIL Absolute Efficiency Oil Filters are specified as 25,000-mile/1-year oil filters.

The bottom line is you are getting a superior product for a lower overall cost while saving yourself time and increasing the performance and life of your engine.

In summary, when you look at the data and facts comparing petroleum oil to a premium quality extended drain interval synthetic lubricant there is simply no comparison. The synthetic product comes out on top in every single parameter. Read and understand the data and facts presented in this book, become an informed consumer, do your research and utilize the absolute best quality synthetic lubricants in your vehicles and equipment.

Email author with any questions: dave@performanceoiltechnology.com

27. WHICH LUBRICATION PRODUCTS ARE SUPERIOR. HOW YOU CAN PERFORM YOUR OWN DATA ANALYSIS AND COMPARISIONS.

By now you can probably determine that I am partial to AMSOIL products. There are many other oils on the market, however my extensive research and testing has not yet been able to find a better oil on the market, nor are there any oil manufacturers that can produce data and test results that show that their oil is superior. I am data and performance driven. I want the absolute best lubricants for my vehicles and equipment and you had better believe that I did my homework when I made the decision to use AMSOIL products many years ago, and the test results and data today still supports that decision 100%. If anyone can show me a better lubricant, then I'll use it, however it hasn't happened yet and it is unlikely that it will happen in the future.

This book is not intended to promote the superiority and benefits of AMSOIL lubricants, but rather an example of the statement of facts supported by data. If another oil company had a better product, then I would be stating the facts as it pertains to their product. You can go out and do your research and see what conclusions you come to once all the specifications and data is reviewed and compared. I've spent many years doing this from my early days in college Fuels and Lubricants Laboratory to my current position as a Lubrication Specialist and Truck/Automotive Engineer. I consult with thousands of companies, race teams and consumers every year and they have done their own research and come to the same conclusions.

Not only that, but during my career as a Detroit, MI Truck/Automotive Engineer I have had the privilege of working with engineers and technicians from one of the most well known and famous race care teams. They use AMSOIL Synthetic Lubricants in their vehicles, as do many other professional race teams, however AMSOIL is not the lubricants that are advertised on their vehicles. The lubricants that are advertised on the vehicles are mainly paid advertising, or sponsorship. I can guarantee you that if there were better lubricants on the market they would be using them. They use the same AMSOIL lubricants that you or I can go out and purchase. There are a few race teams that use the lubricants that are advertised on their vehicles but to my knowledge these are not the exact same lubricants that you and I can go out and purchase at the local auto parts store, or even from the manufacturer directly.

Here is a list of the various major lubricant manufacturers. I challenge you to go out and do your own research and see what you can find. Search the internet, ask the manufacturers to see their product specification sheets and ASTM certified laboratory test data as well as any fleet and field test data.

1. Amoco
2. AMSOIL INC.
3. Castrol
4. Chevron
5. Golden Spectro
6. Havoline

7. Klotz
8. Maxima
9. Exxon-Mobil Corp.
10. Neo
11. Penzoil
12. Quaker State
13. Redline
14. Royal Purple
15. Shell
16. Synergen
17. Torco
18. Valvoline

This list is not all-inclusive, however it covers the major manufacturers and a few of the smaller less widely known ones as well. Each has numerous different types and viscosities of lubricants. Select the specific type and viscosity of lubricant that you are interested on and go out and contact the various manufacturers and gather all the technical specifications and performance data and perform a comparison. I recommend starting your search on the internet and then by contacting each specific company and requesting the data.

The problem you will most likely encounter is that very few manufacturers will release the complete data and specifications that you are interested in, which necessitates that samples of the specific oil be obtained and sent to a test lab and testing performed. I have done this for specific products that I wanted to see the data, because the company in question would not provide the data. After reviewing the results it became apparent why; the performance and test values of some of these products was marginal.

The most common and typical specifications they will provide are the Viscosity Index, Flash Point and the Pour Point. Very few will provide NOACK Volatility, Four-Ball Wear Test, Total Base Number, Kinematic Viscosity, Cold Crank Simulator Apparent Viscosity, Borderline Pumping Temperature and the High Temperature/High Shear Viscosity. In my opinion those are the basics that you should be requesting. If a company cannot or will not provide that data to you then I would be highly suspect as to why not. This is not confidential data and can easily be obtained by laboratory testing.

If a company will not provide you that data please contact me and I can suggest a few test labs that can help as well as provide detailed comparison test data covering many different motor oils. There are highly qualified ASTM and ISO certified test labs nationwide that can perform this testing, although it can get somewhat costly depending on the specific tests required, but if you want the data and they won't provide it this is the only way.

Email author with any questions: dave@performanceoiltechnology.com

28. FREQUENTLY ASKED QUESTIONS REGARDING SYNTHETIC LUBRICANTS

This section answers some of the most common questions people ask regarding synthetic oil. The answers here are brief and to the point. There are areas within this book that address some of these questions in more detail.

Are synthetic motor oils compatible with petroleum motor oils and other synthetics?

Yes, synthetic oils for passenger car and light truck use are fully compatible with petroleum oil and other synthetic lubricants. But, even though they are compatible it is best not to mix different brands of oil. Each brand of oil has a specific chemistry and additive package and two different oils mixed together may result in optimal performance as they were engineered to if the chemistries of the oil becomes offset by mixing with another brand of oil.

I was told that once I change to synthetic I could never change back to petroleum oil: is this true?

That statement is 100% false. You can change back to petroleum oil at any time. If running a petroleum oil you can change to synthetic oil at any time as long as the engine is in mechanically sound condition.

Do synthetic motor oils damage seals?

Absolutely not. Both petroleum motor oils and synthetic motor oils have additives blended in the oil to control seal swell, shrinkage and other engineering parameters.

Can I change to synthetic motor oil at any time?

Yes, you can install synthetic motor oil in any engine as long as the engine is in mechanically sound condition. There is no specific set cast in stone mileage that you can or cannot install synthetic motor oil in an engine, or any other component or system for that matter.

My mechanic tells me that synthetic oil is too slippery for use in engines with roller rockers and wet clutches; is there any truth to this?

Absolutely not; that is a false statement. Synthetic oil is no more “slippery” than petroleum oil. The tractive coefficient, which is a measure of the case by which a lubricant facilitates sliding, is essentially the same for both mineral oils and synthetics. Synthetic oil is more uniform in molecular structure, which reduces frictional resistance but it is not more “slippery” than petroleum oil.

Will using synthetic motor oil void my new vehicle warranty?

Absolutely not. Manufacturers base their warranty requirements on oils meeting API service quality classifications. This does not mean that the oil has to have the API starburst; only that the oil must meets the API service quality classifications. The fact is that a premium quality synthetic motor oil will not only meet these specifications but also exceed them.

What about all the different viscosity oils my owner's manual says I have to use for different outside temperatures, seasons and climates; do I need to use different viscosity synthetic oils as well?

Synthetic motor oils have an exceptionally low pour point (typically around minus 60 deg. F for a premium quality 5W-30, 10W-30 or 0W-30) and an exceptionally high flash point and high temperature/high shear viscosity value. Petroleum oil cannot come close to matching these wide operating temperature ranges, thus necessitating different viscosities for different climates. When using a premium quality synthetic motor oil you do not have to change to a different viscosity for different climates.

Why do some test results showing synthetic oils superiority state "as tested by an independent lab"? Why don't you state which lab did the testing?

First, it is generally against most companies' policies to release that information to consumers, as well as their vendors. It is partly due to confidentiality and partly because some labs do not have customer service departments and can't have retail customers calling them. Instead, take a look at how long the particular company has been in business. It would be terribly hard for a company to stay in business for a long period of time if their advertising is not accurate. Also, the Federal Trade Commission takes a very dim view of false advertising and comes down hard on companies whose products don't perform as claimed. Besides that, if the data is not accurate a competitor is likely to initiate legal action, which can be very expensive. Finally, if a person wants to, they are welcome to take a sample of the product in question to any lab that has ASTM equipment and have the tests run themselves.

Are synthetic motor oils capable of extended drain intervals?

Some are and some are not. The only way to know for sure is to go by the oil manufacturers specifications. This can also be verified by oil analysis testing at different intervals during use. There are two manufacturers that specify 25,000 mile/1-year drain intervals and only one that I am aware of that specifies 35,000 mile/1-year intervals and yet another that specifies 5000, 7,500 or 15,000 mile drain intervals without by-pass filtration. If by-pass filtration and oil analysis is used, then drain intervals can be extended until the lab results indicate the oil needs to be changed. This can be many years and several hundred thousand miles depending on the variables.

Will synthetic motor oil reduce oil consumption?

Yes, synthetic motor oils have been proven to have much lower volatility than petroleum oil as well as improved piston to cylinder sealing and superior oxidative stability, thus resulting in reduced oil consumption. Synthetic oil will not cure an engine that consumes oil due to mechanical issues. Synthetic oil should be used in mechanically sound engines. If you have a known mechanical issue, then repair it before installing synthetic motor oil.

Will synthetic oil cause the wet clutch in my motorcycle to slip?

Whether the oil is a petroleum oil or synthetic is not the issue here. As stated previously, synthetic oil is not more “slippery” than petroleum oil. Both petroleum oil and synthetic oil for automotive use has friction modifiers blended in, which are typically not compatible with wet clutch applications. There are motorcycle specific oils blended specifically for motorcycle applications with wet clutches that should be used in motorcycles. These lubricants do not have any friction modifiers blended in.

Will synthetic oil cause oil pressure to change?

Oil pressure is also directly related to flow volume. Synthetic oil is more uniform in molecular structure and provides less resistance to flow therefore in order to achieve the same flow volume as a petroleum oil, which has a higher frictional resistance to flow, it is possible that under some conditions, such as idling that a slightly lower oil pressure could be noticed, but that the oil flow volume delivered to the engine is adequate for the engine operating RPM and conditions. Synthetic oil has better flow characteristics than petroleum oil and may also cause an engines RPM at idle to increase due to decreased resistance to flow, less internal drag and parasitic losses.

Here’s another way to explain pressure and flow volume: if you have an air tool at requires 90 PSI @12 CFM, you could use a 1 HP air compressor that delivers 90 PSI, however it would not deliver 90 PSI @12 CFM, and would have to work very hard to make the tool operate, however the tool would not operate at maximum capacity due to the lower flow volume. A 10 HP compressor on the other hand would easily provide 90PSI @ 12 CFM and would not have to work very hard to do it. Pressure and flow volume go hand in hand. You can have maximum oil pressure, however if you don’t have the proper flow volume it isn’t going to do you any good. With synthetic oil, and all other engine parameters remaining equal, it takes less oil pressure to achieve an equivalent flow volume of oil than it does with a petroleum oil, and the engine doesn’t have to work as hard to deliver the increased flow volume. Often when changing to a synthetic motor oil the engine RPM may increase at idle due to decreased internal frictional resistance of rotating and sliding components.

At high engine operating temperatures synthetic motor oil will be much more shear stable and will not drop nearly as much as petroleum oil does. I recently had a friend with a jet boat with a 460 cu. in. racing engine. After one mile full speed run across the lake with a 20W-50 petroleum oil the oil pressure went from about 45 psi down to about 15-20 psi. After changing to a premium quality synthetic 20W-50 motor oil and after the same one mile full speed run across the lake the oil pressure only dropped to about 35 psi. That is the direct result of the superior high temperature characteristics of synthetic motor oil and its ability to resist the effects of intense shear forces.

I am using an extended drain interval synthetic oil but my change engine oil light is on. Do I have to change the oil?

Oil sensors and oil change lights **do not and cannot perform spectrographic or laboratory chemical analysis on an oil** (the proper method to determine an oils suitability for continued service). They typically monitor certain engine operating parameters and use an algorithm to predict when the oil light should come on. If you are using an extended drain interval synthetic oil, such as a 25,000 mile/1-year or 35,000 mile/1-year oil, and the oil light comes on simply reset it and follow the oil manufacturers change recommendations.

Email author with any questions: dave@performanceoiltechnology.com

29. MOTORCYCLE CRANKCASE OILS

Motorcycle crankcase oils are specially formulated for motorcycle applications that have wet clutches. Most automotive oils are not suitable for use in motorcycle engines. A premium quality motorcycle specific oil typically has higher levels of anti-wear chemistry such as zinc and phosphorus than some automotive oils do, which are critical in protecting high RPM and high load and engines from wear and especially cam lifters and follower wear. That is not to say that all motorcycle oils have increased levels of zinc and phosphorus; many do not.

Over the years, automotive manufacturers have requested oil manufacturers to reduce zinc, phosphorus (an essential element in ZDDP, Zinc Diethyl Dithiophosphate) and other extreme pressure additives from the oil. The primary reason is that automotive manufacturers have requested is that they are extending emissions systems warranties to periods of 10 years/150,000 miles and they claim that high concentrations of these chemical additives were contaminating their catalytic converters and negatively affecting emission levels required to meet their 10 year/150,000 mile warranty requirements. There are also a few motorcycles on the market that have catalytic converters, however they are not subject to the same 10-year requirements as the automotive industry for emissions levels.

I recommend looking at the oil manufacturer's specification sheet and performing a comparison. If they won't provide the data a very simple spectrographic analysis lab test can be performed that will provide the exact PPM (parts per million) concentration of zinc, phosphorus and other chemicals. That is the only way to get accurate information. There is no reason why a reputable oil manufacturers customer technical service department should not have that data (as well as all the other ASTM test data references in this book) readily available for the consumer and if they do not I would be highly suspect as to why not and go out and get the data myself before I started using their oil.

Another issue with using an automotive type oil in a motorcycle with a wet clutch is that many automotive oils have friction modifiers. Friction modifiers in automotive oils tend to provide increased frictional reduction and offset a portion of the fuel economy lost when the U.S. Government mandated a reformulated gasoline for emissions requirements. However these friction modifiers can be detrimental to proper wet clutch operation and can cause slippage and other potential performance issues such as "engine start failures, a rough running feel and increased fuel consumption due to higher engine stall speeds" (kk).

It is also important to note that there are automotive type oils that do not contain friction modifiers. You have no way of knowing unless the specific manufacturer tells you. That is why I say it is better to be safe and use a motorcycle specific oil in a motorcycle engine with a wet clutch that meets the proper motorcycle specification as stated in the next few paragraphs.

A premium quality motorcycle engine oil can be stated to meet the requirements of API Service Classification SL, SJ, SH, SG, SF, CH-4, CG-4, CF-2, CF and CD. Note that SH, SF, SG and CD are now obsolete. Motorcycles specifying an oil meeting any of the obsolete applications can use an oil with the newer classification oil because it includes, and supercedes, the requirements of the obsolete service classification. For example, if you have an old motorcycle that specifies SE service classification you do not have to go out and look for an oil with that service classification (and if you did you would most likely not be able to find any in stores as SE was outdated in 1979). The newer classifications include the outdated ones and are perfectly suitable for use. There are some motorcycle oil manufacturers that will include an older service classification on the bottle to so that consumers can specifically see that the oil not only meets all the older specifications but the newer ones as well.

It is important to note that as an oil classification is superceded by a newer one, that the newer one provides improved benefits over the older one in such areas as high and low temperature deposits, wear, rust and corrosion for example and is perfectly suitable for use. **All quality motorcycle specific oils should also carry the JASO Motorcycle Specifications, which are either the JASO-MA specification (no friction modifiers) or the JASO-MB specification (with friction modifiers).** The JASO-MA rating specifies that no friction modifiers are used. Note that the JASO-MB motorcycle does have friction modifiers, but is designed for motorcycles that specify the JASO-MB specification. If the oil does not carry one of these specifications, even if the other specifications listed above are present, I recommend finding an oil that has the proper JASO specification clearly labeled on the bottle. The latest JASO specification is JASO MA2 which is meant to impart smooth clutch operation, smoother gear shift and enhanced engine protection.

One specific manufacturer, AMSOIL INC., offers a 10W-40 and 20W-50 Motorcycle Oil which meets API SG, SL/CF. JASO MA/MA2 and GL-1 Gear Lube Specifications. This is the only oil on the market that meets all these specifications concurrently. The GL-1 Gear Lube rating provides for superior gear protection in motorcycle gearboxes which are integral with the crankcase as well as in motorcycles that have separate transmissions and primary drives, such as with Harley-Davidson Motorcycles.

Petroleum or Synthetic?

On the subject of whether or not to use a petroleum or synthetic motorcycle oil my recommendation is to use a premium quality synthetic. There is absolutely no comparison between the two. Synthetic oil has been proven to resist high temperature breakdown and shearing effects at higher engine operating temperatures for a much longer time period than petroleum oil and as a result allows the oil to stay in the specified viscosity grade much longer. Synthetic oil is more uniform in molecular structure and will reduce internal friction and thus provide for lower engine operating temperatures as well as provide for smoother shifting.

I have measured the cylinder and cylinder head operating temperatures in two identical motorcycles; one running petroleum oil and the other a premium quality synthetic. I measured an average of 15-20 degree F. temperature difference after a very mild ride and short period of idling. At extreme engine operating temperatures and conditions this value can be up to 35-45 degrees F. lower with synthetic oil. I have received reports of this from motorcyclists that have oil temperature gages installed in their crankcase. I received another report of a customer that when he was using petroleum oil in hot summer heat and traffic jams he would have to shut off his air-cooled V-twin engine because it began overheating. After changing to a premium quality synthetic motorcycle oil his engine temperatures dropped significantly and he no longer had that problem on hot summer days in traffic. Again there is no comparison between the two and anybody that tells you otherwise has obviously not reviewed documented test data and facts clearly showing that synthetic oil outperforms petroleum oil in every category.

I have a report of a dynamometer test run comparing a specific manufacturers branded motorcycle oil to a premium quality synthetic oil. In the first part of the test with the petroleum oil installed in the engine, transmission and primary chaincase the maximum horsepower (Hp) was 68.1 and the maximum torque was 80 lb.-ft. In the second part of the test the same motorcycle was used and all petroleum oil products drained from the engine, transmission and primary chaincase. With the synthetic the maximum Hp was 69.8 and the maximum torque was 81.3 lb.-ft. That’s a gain of 1.7 Hp and 1.3 lb.-ft. torque, which is what I consider a significant amount of gain just from changing from petroleum oil to a premium quality synthetic oil (ll).

Synthetic oil will hold contaminants in suspension longer and reduce any oxidation and provide for a much higher load capacity as well as provide for increased wear protection to critical engine parts such as pistons, cylinders, gears, camshafts and bearings. Synthetic oil also has superior cold weather performance characteristics and will flow at temperatures that will cause petroleum oil to solidify and can be used for extended drain intervals beyond that of a petroleum oil. Note that during extended drain interval operation you need to change the oil filter at the filter manufacturers recommended change intervals, then install a new filter, top off the oil and your ready to go. There are premium quality extended change intervals oil filters on the market that can be used for twice as long as a standard filter.

Synthetics and Slipperiness in Relation to Roller Rockers and Wet Clutches

As a side note I have received reports of some motorcycle shops telling customers that synthetic oil is so slippery that is causes roller bearings not to roll and will result in flat spots on the roller bearings. This is absolutely not true. Synthetic oil is no more “slippery” than petroleum oil. Synthetic oil is more uniform in molecular structure than a petroleum oil but it is not more slippery and will certainly not cause roller bearings to roll. Roller bearings will roll whether they are using petroleum oil or synthetic oil and the only way the roller bearing on the rocker arm will ever stop rolling is if the needle bearings that support the roller bearing failed. Every automotive racing engine (as well as many other types of high performance engines) and most of today’s high performance automobile engines use camshafts with sophisticated roller rockers with absolutely no problems of this nature whatsoever.

I have also received reports of motorcycle shops telling customers that synthetics are so "slippery" as compared to petroleum oils (which simply do not reduce friction as well) that wet clutch packs in their motorcycle transmission and even their automatic transmission of their cars and trucks will slip when using "slippery synthetics" even if there are no friction modifiers present. This is absolutely not true.

Look at it this way. Wet sandpaper removes paint as well as dry sandpaper does. The slipperiness of the water does not impede the sandpaper's ability to function. The same applies to the slipperiness of synthetic lubes in wet clutches. It is simply not an issue. However, just as rinsing the sandpaper keeps it cleaner longer so it functions better longer, so the synthetic lubricant keeps wet clutch plates cleaner longer so they function better. And, since synthetics are superior cooling agents to conventional petroleum lubes, using synthetics will help wet clutches last longer, too.

Petroleum oils have low resistance to heat and allow varnish and glaze to form on clutch plates, which can lead to slippage and increased heat generation and potential failure of the clutch pack. Synthetic oil is going to allow your wet clutches to perform better (especially under extreme heat, RPM and load conditions) and last longer than they would with petroleum oil subjected to the same operational conditions.

Also, in respect to Automatic Transmission Fluid, which also operates in clutch packs; synthetic ATF is not more "slippery" than petroleum ATF. The base fluids, whether or not petroleum oil or synthetic oil, play no direct role in the relative friction levels of wet clutches. The friction-modifying additives developed for petroleum oils work just as expected in synthetic PAO's fluids. The longer the fluid resists oxidation, the longer the original frictional properties remain. The superior oxidative stability demonstrated for synthetic ATF's thereby leads to extended retention of frictional properties (a).

Which Viscosity and How Long Can You Use It For?

When it comes to motorcycles oils the most common choices are 10W-40 and 20W-50. There is also SAE 50W and SAE 60W oil that is generally specified for older Harley-Davidson motorcycles with Flathead, Panhead or Shovelhead engines. There is also a 0W-40 and a 5W-40 motorcycle oil which is generally used in 4-stroke off-road motorcycles and ATV's and for machines used in cold weather operation, although a 10W-40 synthetic has an exceptionally low pour point and is also suitable for use in cold weather operation as well as extreme high temperature operation (again, due to the superiority of synthetic oils as outlined in this section and book). In general, 10W-40 is best for most of the Japanese machines and the 20W-50 is best for V-Twin engines, such as used in Harley-Davidsons. For specific recommendations consult your owners manual as there are exceptions to this.

Motorcycle oil drain intervals should be performed at the manufacturers specified oil drain interval unless you are using one of the premium quality synthetic oils on the market which specifically state that is can be used for twice as long as manufacturers recommendations. If you have a particular brand or type of oil and you want more exact change interval and performance intervals, other than the motorcycle manufacturers recommendations, then your option is to perform used oil analysis testing over a period of time in order to establish a trend of how long the oil is suitable for continued use based on your motorcycle and operating conditions. That is the only accurate method that will assist you in determining exactly how well the oil you have chosen holds up over a period of time in service. Oil analysis testing is covered in detail in Section 20 of this book.

Performance Test Comparisons, one specific manufacturer, AMSOIL INC., has recently performed and published the most comprehensive testing of motorcycle oil ever conducted, called “A Study of Motorcycle Oils”. The 26 page report includes test data comparing 12 SAE 40W Motorcycle Oils and 16 20W-50 Motorcycle Oils. If you are interested in reviewing the study please contact me.

Email author with any questions: dave@performanceoiltechnology.com

30. AUTOMOTIVE GEAR LUBRICANTS

This section will cover gear lubes in relation to automotive and some truck applications. There are numerous other types of gear lubes for industrial applications that utilize different types of gear sets, however they will not be covered in this book. The SAE has established viscosity grades for gear lubes just as they have for engine oils.

The most common SAE viscosity grade gear lube used in production cars and light trucks is 80W-90. 75W-90 is also a very common viscosity grade gear lube. If your vehicle specifies 80W-90, as many production vehicles do, you can certainly use a 75W-90. There is very little difference between the two. According to SAE J306 specification the maximum temperature for a viscosity of 150,000 centipoise for a 75W is minus 40 deg. C. while the value for an 80W is minus 26 deg. C. This simply means that the 75W is going to flow slightly better under colder temperatures than the 80W will, but nothing that you will ever be able to detect without very specialized test equipment. Both viscosity gear lubes will protect equally well and are both 90 weight gear lubes at normal operating temperatures.

Many light, medium and heavy-duty trucks will specify an 75W-90 or an 85W-140. In the case of the 85W-140 you can use either an 85W-140 or a 75W-140. The differences are in cold weather flow properties and extremely minimal. The 75W-140 is going to flow slightly better than the 85W-140 in cold weather until the gear lube warms up in which case they will both perform as a 140 weight gear lube. Many synthetic gear lubes will show SAE grades of 75W because of their excellent low temperature characteristics. In the future 75W-110 gear lubes will become popular as manufactures strive to maximize protection while maximizing fuel economy.

Synthetic Gear Lubes

There are several manufacturers are using a synthetic 75W-140 gear lube in some light trucks and performance vehicles while a few also use a synthetic 75W-90 in some high performance cars and trucks. One of the first production applications of a 75W-140 synthetic gear lube I can remember in a production light truck was in a very performance model that was having heat related problems in the rear axle that was causing the plastic housing of the 3-channel anti-lock system (ABS) sensor located in the differential housing to overheat and distort.

In a typical ABS system there is a toothed sensor at each wheel that measures wheel speeds and compares them using sophisticated computer technology and can determine which wheel or wheels is locked up and then send a signal to the ABS unit to modulate brake pressure. This is called a 4-channel system. A 3-channel ABS system is a less costly type of system and only has one sensor at the rear differential and one at each front wheel, thus the name 3-channel ABS system. The only way to solve the problem was to use a synthetic 75W-140 gear lube in the axle. The synthetic gear lube lowered the temperatures significantly and eliminated the problem, as well as provided for increased performance and durability of the gear set and axle bearings. You will see that several manufacturers are now using and specifying synthetic gear lube for axles, especially in the rear axles of trucks. The synthetic gear lube is used for a reason. A manufacturer is generally not going to use a higher performance and more costly gear lube unless it is necessary to solve a specific problem or improve performance or durability issues. The synthetic gear lubes that are used as a factory fill are superior to petroleum gear lubes.

When it comes time to change the factory fill synthetic gear lube I recommend purchasing one of the premium quality synthetic gear lubes manufactured by AMSOIL INC. The performance is superior and the cost is significantly less that you will pay by purchasing it from the dealership. The specifications state that in non-commercial normal service car and light truck applications their gear lubes have a change interval specification of 100,000 miles. In severe service the change interval specification is 50,000 miles. For heavy trucks change intervals range from 250,000 miles to 500,000 miles.

If your vehicle originally came with a petroleum gear lube I recommend upgrading to a premium quality synthetic gear lube. Synthetic gear lubes operate at different temperature ranges in relation to viscosity than petroleum gear lubes do. This allows for one gear lube to cover a wide range of operational, temperature and load conditions from extreme cold to extreme heat. PAO's are the most commonly used base stocks for synthetic gear lubes for automotive applications and are formulated without any viscosity index improvers (VI's) since PAO's have a natural high viscosity index of the base fluid. For example, "a synthetic 75W-90 gear lube will flow to temperatures as low as minus 40 deg. C. while a petroleum based 80W-90 gear lubricant's flow is retarded at these very low temperatures (a)".

Synthetic gear lubes are also is much more shear stable. A petroleum multi-viscosity gear lube will contain VI's in order to meet the viscosity-spread requirements while the synthetic multi-viscosity gear lube will not. In a test of two different trucks using 75W-90 petroleum and synthetic gear lubes, the truck with the petroleum gear lube actually "sheared out of grade, lowering the viscosity considerably. The gears from this test showed excessive wear indicative of low viscosity. By comparison, the truck with the synthetic based PAO showed very little shear loss and showed acceptable performance at the end of the test (a)". Synthetic gear lubes are also superior in the areas of oxidative and thermal stability and there is significant data supporting this fact from both axle manufacturers and synthetic oil manufacturers, however it is not my intention to review the data in this book. Synthetic gear lubes will also allow for a reduction in lube temperature, easier shifting in automotive manual transmissions and gearboxes such as on motorcycles and also show a significant improvement in cold weather shifting performance

Friction Modifiers

It is also important to note that manufacturers also specify a friction modifier, typically 4-oz., to be added when gear lube is replaced in an axle that has a factory (or aftermarket) limited slip differential. With some synthetic gear lubricants this is typically not the case.

As discussed previously, synthetic lubricants are not more "slippery" than petroleum gear lubricants. I recently had a customer that was told he needed to use twice as much friction modifier with a synthetic gear lube due to the increased "slipperiness" of synthetics. Again, this is not true. I know of several premium quality synthetic gear lubricants that do not require any friction modifiers to be added with limited slip differentials. Check the gear lube manufacturers specification to determine if a friction modifier is required before putting it in. It will be of no benefit if you install it when it is not needed. The best way to determine if a friction modifier is required is to, after installing the synthetic gear lube in a limed slip axle, go out and drive the vehicle as you normally would but also be sure to make several tight right and left turns, or find a location where you can safely and slowly drive in a figure "8" pattern for a minimum of eight to ten repetitions. If you notice any chatter on turns then you most likely need a friction modifier and you can take out the differential filler plug and add it very easily. If you do not get any chatter then you do not need friction modifier.

Extreme Pressure Additives and Performance

Another important aspect of gear lubes to consider is extreme pressure (EP) performance and additives. Both petroleum and synthetic gear lubricants utilize EP additives where film strength and extreme pressure performance are needed to combat high shock loading of the gears. Sulfur, phosphorus and/or chlorine based additives are often used, although "chlorine is not fully effective or may cause corrosion concerns where water is present (d)". The most common EP additives are a sulfur-phosphorus combination in automotive gear lubes.

Extreme pressure additives are activated by heat rather than by pressure. When activated by heat they then chemically react with the metal surfaces on the gears to form a film that wears or polishes off slowly rather than allowing the mating surfaces to weld together causing destruction of the gears, bearings and even axle shafts once metal particles and fragments are loose inside the axle housing and are circulated by the gear lube.

Note that it takes time in service for this protective film to develop but once that it has developed it has a lower shear strength than the metal used for the gears and thus reduces friction and heat. These sulfur and phosphorus compounds can also tend to be corrosive to non-ferrous parts. There are different GL ratings for different type of gear lubes and applications. Applications requiring a gear lube which is "friendly" to non-ferrous parts (such as in marine outboard and stern drive lower unit gears and certain manual transmissions, which use aluminum or magnesium cases and other non-ferrous bushings and components) typically will specify a GL-4 rated gear lube which has a different EP additive chemistry and is compatible with the non-ferrous components.

The GL ratings are specified by the API and are as follows:

GL-1: Specified for automotive spiral-bevel and worm gear axles and some manual transmissions subject to mild service and that can be sensitive to some EP additives.

These lubes usually contain rust and oxidation inhibitors, defoamants and pour point depressants but do not contain any EP additives or friction modifiers.

GL-2: Specified for automotive worm gear axles that are subject to more severe service than that which is covered under the GL-1 specification.

GL-3: Specified for manual transmissions and spiral-bevel axles operating under moderately severe service.

GL-4: Specified for hypoid gear service without shock loading, but still moderate to severe service (high speed/low torque and low speed/high torque). These lubes may be used in manual transmissions and transaxles where EP additives are acceptable and typically contain a different zinc additive combination. This classification is still commonly used, but is also obsolete. It is also a commonly specified for marine outboard and stern drive lower unit gears and bearings where the manufacturer specifies GL-4 rated performance. GL-4 rates lubes are not recommended as a replacement for GL-5 rated lubes. "GL-5 rated lubes shows significantly better anti-wear (anti-score) properties than GL-4 rated oils under similar service conditions (d)"

GL-5: Specified for hypoid gears under shock loading and severe service operating conditions used in cars and trucks. This is the most common and widely used specification today. These lubes have a high level of EP additives and, depending on the manufacturer and formulation, could be mildly corrosive to non-ferrous parts in certain applications.

GL-6: This classification is obsolete and/or was never formally adopted by the API, although I have seen some racing type gear lubes advertised as "high-performance GL-6". It is more than likely advertised this way for marketing purposes.

API MT-1: Specified for manual transmissions that do not have synchronizers. The oxidation level and thermal stability is higher than GL-1, GL-4 and GL-5 (z).

MIL-PRE-2150E: Specified by the military for automotive gear lubes. It combines the requirements of API GL-5 and MT-1 (z).

Note that in although the previous lubricant specifications have generally provided satisfactory levels of performance for current automotive gear units, some difficulties have been experienced in low-temperature service because operating temperatures are not always high enough to fully activate the various EP agents. This disadvantage is usually overcome by using a higher dosage level of additive in lubricants intended specifically for arctic-like service (z). In cases such as arctic-like service synthetic gear lubricants will be a major improvement over petroleum based gear lubricants. I know of some auto manufacturers that install synthetic lubricants in vehicles destined for areas that experience extended arctic weather conditions.

Email author with any questions: dave@performanceoiltechnology.com

31. AUTOMATIC TRANSMISISON FLUIDS

The hydraulic fluid used in automatic transmissions is a very specialized fluid because it is required to do a lot more than just lubricate. It is subjected to very severe service and is one of the most complex fluids used in an automotive system. The primary functions of an automatic transmission fluid (ATF) are:

1. To transfer power from the engine to the driveline via the torque converter.
2. To absorb and transmit heat from the torque converter to the cooler located in the front of the vehicle and to act as a clutch pack friction element coolant. It must absorb and dissipate the heat energy dissipated by a clutch or band engagement.
3. To transmit hydraulic pressure through a complex hydraulic control system which uses valves, servos, pumps, clutch cylinders and fluid lines and passages.
4. To act as a lubricant and coolant for the planetary gears, bearings, servos, clutches and bushings.

An ATF can be subject to extremely high temperatures during engagement of clutch plates and this must be absorbed and dissipated effectively. If the transmission fluid cannot withstand the heat it will oxidize and can result in destroyed friction materials, sticking valves and servos and plugged passages and filters. An ATF must also have high resistance to varnish and sludge build-up that results from high heat generated in the torque converter. It must also reduce wear and corrosion, prevent foaming and act as a sealant and control the quality (shift feel) of the clutch and band engagement. It must be fully compatible with the materials used in within the transmission such as seal materials and friction plates. An ATF must also be able to maintain a stable viscosity throughout a wide range of operating conditions and temperatures. At low temperatures it must be “thin” enough to be able to flow for proper cold weather shifting but not so “thin” that it cannot effectively operate the pumps, pistons and servos in order to maintain proper hydraulic pressures at high operating temperatures.

This is a simplified overview intended to demonstrate the complexity required of an automatic transmission fluid. It is not my intention to cover the intricacies of how an automatic transmission functions or the specific details of base stocks chemicals and additives engineered into an ATF.

The main types of ATF in use today for cars, light trucks and some heavy trucks are: GM Dexron II, III and VI, Ford Mercon, Mercon V and SP and Chrysler ATF+ thru ATF+4, Honda Z1, Toyota T and T-IV, Allison C3 and C4 and many others including Mitsubishi, Mercedes, BMW, Nissan, Caterpillar and ZF. Automotive and truck manufacturers perform extensive testing prior to releasing a specific ATF for their vehicles. When it comes time to service your ATF make sure that you select a fluid that is recommended for your specific vehicle and transmission.

Most common petroleum ATF’s are specified to be changed at approximately 15,000 to 30,000 mile intervals. Many automotive manufacturers have recognized the need for superior transmission fluids that can withstand severe operating conditions for longer periods of time and now there are some manufacturers that specify 50,000 mile changes or even 100,000 mile changes under **normal operating conditions**. Towing heavy trailers, hauling heavy loads, stop and go driving and/or other severe operating conditions can significantly reduce these recommend normal service intervals. These extended drain interval specified fluids are either a synthetic or a semi-synthetic blend. The automatic transmissions on passenger cars and light trucks are typically one of the most neglected service items. The extended drain intervals specified on many newer vehicles are the manufacturers response to address these issues, **however I must stress again that these recommended extended service intervals are for normal operating conditions**.

The semi-synthetic blends are typically a petroleum ATF with 10-20% PAO's added to the fluid. The PAO's lowers the temperature at which the fluid forms a wax gel but the other advantages that accompany the small amount of PAO such as improved oxidation resistance or flash points are small or negligible (a).

I have also seen some newer vehicles that have no ATF filler tube. At 100,000 miles (based on normal service conditions) the vehicle is supposed to be taken into the dealership and have the fluid pumped out using a special fluid exchange machine. The machine will pump all the old ATF out and pump the new fluid in with an efficiency in the 98-99+% range, meaning these machines are highly effective in getting the old fluid out and the new fluid in. I also recommend these machines for anyone that is changing their fluid from a petroleum ATF to a premium quality synthetic ATF. The cost to pay to have this service performed is very nominal and will save you a lot of time and headaches than if you try to do the job yourself. You cannot get enough fluid out by simply doing a pan drain and refill. You'll still have a lot of old fluid in the torque converter, valve body, pumps, lines and cooler. Just make sure you take it to a reputable and qualified service center and that the premium quality synthetic you bring them actually is put in the vehicle.

Also, it is a good idea to have a new filter installed at this time so you know exactly when it was changed. Normally, ATF filters do not need changing very often. I personally install the new filter when I install the synthetic ATF and then I will not change again it unless something in the oil analysis test results indicate it is necessary to change the filter or the fluid, or at approximately 100,000 miles. I also install remote ATF fluid filters under-hood on my vehicles, which adds an increased measure of filtration protection as well as makes it very quick and easy to service the filter.

I highly recommend using a premium quality synthetic ATF vs. a petroleum ATF or a semi-synthetic blend. The benefits of using a premium quality synthetic lubricant include significantly lower operating temperatures. Heat is the killer of automatic transmissions. I have measured these differences with transmissions that have been instrumented with thermocouples and specialized recording equipment, however it is also dependent on the vehicle operating and load conditions. A premium quality synthetic ATF will also provide exceptional resistance to oxidation and thermal degradation and maintain a very stable high temperature viscosity. Low temperature performance is excellent as well as significantly improved anti-wear performance along with extended drain intervals in the range of three times longer than petroleum oil under normal service conditions. As previously stated with engine oils I also recommend performing periodic oil analysis testing on your synthetic ATF in order to get an accurate reading of how well it is performing and when it may need to be changed.

Please note that in reference to the friction material in automatic transmission clutch packs synthetic ATF is not more "slippery" than petroleum ATF. The base fluids, whether or not petroleum oil or synthetic oil, play no direct role in the relative friction levels of wet clutches. The friction-modifying additives developed for petroleum oils work just as expected in synthetic PAO fluids. The longer the fluid resists oxidation, the longer the original frictional properties remain. The superior oxidative stability demonstrated for synthetic ATF's thereby leads to extended retention of frictional properties (a).

There is also one manufacturers brand of premium quality synthetic ATF (AMSOIL INC.), which covers all major domestic and foreign manufacturers specifications with one ATF. This is the only ATF of this type that I am aware of that is available. It is a highly complex fluid formulation and to date no other manufacturer has been able to formulate a similar type of ATF. It is also one of the company's most highly guarded trade secrets and is recommended to cover many different transmission applications and has a service life under normal conditions of 100,000 miles.

Email author with any questions: dave@performanceoiltechnology.com

32. MANUAL TRANSMISSION AND 4X4 TRANSFER CASE LUBRICANTS

It is extremely important to follow the manufacturer's recommendation when it comes to manual transmissions and transfer cases. The days are long gone when manual transmissions and transfer cases all used gear lube. Today, these fluids can be a gear lube, ATF, motor oil or a specially engineered and manufactured transmission fluid.

In the case of an ATF the manufacturer will typically tell you that it does use ATF and specify which ATF must be used. Follow those recommendations and do not substitute a gear lube in a transmission that is specified to use ATF or vise versa. Most manufacturers will also tell you when a gear lube is specified and the specific viscosity and API GL rating. However, there are some manufacturers that do use a commonly available gear lube but will not specifically state that; instead they choose to cleverly market it as a "dealership only" type fluid with a special part number and a high price to go along with it.

I have found this to be the case with a few specific manufacturers of a manual transmission that have their own part numbers and specifications. Testing and specification analysis has indicated that these fluids are in one case a 5W-30 motor oil and in another case a 75W-90 gear lube, however nobody at the dealership knew that and they continued to insist that their "special" lube must be used, for "warranty purposes."

In most cases there is a premium quality synthetic fluid or lube, which is often priced well below the cost of the manufacturers "special" product. A premium quality synthetic manual transmission or transfer case fluid or lube will outperform and out protect a petroleum fluid or lube and is highly recommended. Benefits include smoother shifting, exceptional low and high temperature performance and wear protection and lower gearbox operating temperatures.

AMSOIL INC. manufacturers a superior quality Synthetic Manual Transmission and Transaxle Gear Lube and a Synthetic Manual Synchromesh Transmission Fluid that is recommended to cover many different automotive and light truck recommendations at a price that is less than the manufacturers branded lubricants.

Email author with any questions: dave@performanceoiltechnology.com

AUTOMOTIVE BRAKING SYSTEMS- ROUGHNESS AND VIBRATION SERVICE AND CORRECTION PROCEDURES. MAXIMIZING VEHICLE LONGEVITY

One of the most common brake system customer vehicle performance complaints is brake roughness, pulsation and vibration. As common as this complaint is very few people, including many service technicians, actually understand the true cause of it and what to do to correct it permanently. This leads to misdiagnosis, unnecessary repairs and parts replaced and the likely re-occurrence of the problem a short time later. Brake roughness can be defined as vibration that is felt in the steering wheel, brake pedal and/or seat during vehicle braking. This does not include the normal pulsation that occurs when anti-lock brakes are activated during a panic stop or when on wet, snow or ice covered roads, which can activate the anti-lock brakes.

What typically happens is the customer experiences this type of vibration and pulsation and thinks something is wrong with their brakes and then takes their vehicle into a repair facility. The customer explains the problem and the repair facility technician or service writer either takes the vehicle out for a test drive to confirm the symptoms or pulls it into the shop and starts right in on the brakes. Then they come out to the customer and inform them that their brake rotors are "warped" and they need new rotors and pads (and sometimes hubs), or they can machine the rotors on their bench lathe if there is enough rotor material remaining to meet the manufacturers minimum thickness requirements.

The problem with this diagnosis and repair procedure is that first of all is that **brake rotors do not warp.** The second problem is that replacing a brake rotor with a new brake rotor or machining the rotor on a bench lathe will only fix the problem temporary. The problem will almost always re-occur after a period of time, thus necessitating further repairs. Brake rotor disc thickness variation or excessive lateral runout, as well as drums that are out of round can cause vibrations and pulsations in the brake pedal and/or steering wheel. Brake lining material transfer onto the rotor can also have an effect on this as well.

Here's what really occurs: all brake rotors and hubs have an associated **Lateral Runout (LRO).** LRO occurs when two axes are not parallel to each other, such as the axes of the rotor and the hub or the spindle and the rotor/hub. LRO may be caused by manufacturing tolerances, improperly torqued wheel nuts (uneven or excessive torque), corrosion between the brake rotor and the hub, hub with excessive runout, worn or improperly adjusted wheel bearings or any damage or wear. This is what is commonly referred to as "warped" rotors. These so called "warped" rotors do not in and of themselves cause the vibrations and pulsations. Any machined component, such as brake rotors and hubs, are going to have manufacturing tolerances, which include runout. Typical original equipment new rotor runout specifications are in the range of 0.0015-0.002 in. while low quality aftermarket rotors can be significantly higher. In addition to excessive manufacturing tolerances, cheap, low quality aftermarket rotors can have increased impurities and porosity in the metallurgy. I recommend using either the OEM rotors or a high quality aftermarket rotor.

New rotors and hubs are machined to precision tolerances from the auto manufacturers. Aftermarket rotors and hubs are usually not machined to the same tolerances, as the aftermarket manufacturers do not know the OEM specifications, although some are much better than others.

Auto manufacturers will either match mount the rotor and hubs or machine the rotor on the hub unit as an assembly. Match mounting is matching up the low spot on the brake rotor with the high spot on the hub. This match mounting process minimizes the runout of the assembled components, but is only a production process. A service technician cannot effectively determine where the high and low spots are in order to match mount the components. Machining the rotor on the hub (and/or spindle) with the proper on-vehicle machining equipment is the very best method and almost completely eliminates runout. But, if they do not effectively prevent rust and corrosion in the joint, over a period of time it will induce runout and eventually brake roughness.

What can occur over a period of time is that whatever runout is in the system coupled with improperly torqued wheel nuts and/or misadjusted or loose wheel bearings and rust and corrosion forming between the rotor and hub surface leads to increases in runout. As you drive your vehicle **without using the brakes**, such as on the highway, every rotation of the rotor high spot or multiple high spots contacts your brake linings in the caliper, even when you are not using the brakes and wears the high spot or multiple high spots off the rotor which causes a thin spot or multiple thin spots. Over a period of time this repeated process causes what is called **Disc Thickness Variation (DTV).** DTV is when the rotor thickness is not the same all the way around the rotor. DTV is typically caused by lateral runout. DTV can only be measured with very specialized laboratory testing equipment or with special on vehicle capacitance probes.

When you apply your brakes, and a brake rotor has DTV, the thick and thin spots on the rotor cause the brake pads to move in and out. This in-and-out pad motion causes increases and decreases in brake system pressure, which the driver can feel in the brake pedal. This in-and-out pad motion causes a varying brake force, which is passed to the steering wheel. As the rotor gets hot, it is much more likely to increase thickness variation, thus increasing pedal pulsations as well as steering wheel and other vehicle vibrations. This phenomenon is what many technicians refer to as "warping", however they actually think the rotor warped and needs replacement. Typical acceptable values for DTV are around 0.0004 in. That's 4 ten thousandths of an inch! As DTV increases beyond 0.0004 in., brake pedal, steering wheel and vehicle vibrations and pulsations will almost always occur.

Replacing a rotor with excessive DTV with another new rotor will only correct the problem temporarily, because eventually the associated LRO with the new rotor will lead to DTV over a period of time, and the problem repeats itself all over again. Machining a rotor with excessive DTV on a bench lathe will only temporarily correct the problem because the rotor is being machined true to the bench lathes spindle and not the spindle on the car, plus the spindle on the bench lathe has its own runout.

The correct method is to machine the brake rotor on the vehicle using an on-vehicle brake lathe. For applications where the rotor is separate from the hub (loose rotor) make certain that both surfaces are free of rust and corrosion and be sure to put a thin layer of nickel anti-seize on the mating surfaces. This will prevent rust induced increases in LRO over a period of time. Rust can form in-between the mating surfaces and exert tremendous forces which will cause increases in tension of the wheel studs and resulting clamp load variation which creates LRO. The LRO will then eventually lead to DTV, brake roughness and vibration. For vehicles with adjustable wheel bearings, be certain to properly adjust the bearing preload prior to machining the rotor.

Brake drums still must be machined on bench lathes as there is no method to machine a drum on-vehicle. Drum brake systems are less sensitive in terms of tolerancing that can cause vibrations and pulsations. Most newer model vehicles these days have 4-wheel disc brake systems. Both front and rear rotors can be machined on-vehicle. Note that I recommend machining new rotors on vehicle as well. That way you can be 100% assured that the entire assembly (rotor, hub and spindle) is a matched and perfectly machined rotating assembly. In addition, make sure the caliper slides freely on the caliper pins or slide mechanism, which will minimize off-brake contact of the brake pads with the rotor.

The on-vehicle brake rotor machining equipment that I recommend which performs the absolute best job is the Pro-Cut On-Vehicle Brake Lathe. It is simply the absolute best on-vehicle brake lathe on the market; the competition doesn't even come close to the results achieved with the Pro-Cut. The Pro-Cut is recommended and approved by Ford, GM and Daimler-Chrysler as well as many other car companies.

I have measured finished LRO values of less than 0.0005 in. with the Pro-Cut, which is less than the tolerances on new rotors. In addition the Pro-Cut uses special cutting bits that produce the proper non-directional micro-finish. The Pro-Cut lathe attaches to the hub and is computerized in order to measure runout of the entire system automatically and compensate for it prior to machining so that a perfect cut is achieved every time. Do not allow a caliper mounted brake lathe to be used on your vehicle. Caliper mounted brake lathes mount on the caliper mounts which are machined in different planes with different cutting tools, therefore a few thousandths difference at the caliper mount will produce a finished machined rotor with runout machined in which will eventually lead to DTV and brake roughness.

Now you know what to do next time a repair facility or anyone else tells you your brake rotors are warped. You can explain to them that brake rotors do not warp and that you want your rotors machined with a Pro-Cut On Vehicle Brake Lathe. If they don't have one then call around to find a facility that has one, or contact Pro-Cut directly at www.procutinternational.com, and they will tell you where your nearest service center is that has a Pro-Cut.

WHAT ABOUT BRAKE LININGS?

How many times have you gone into the local auto parts store to purchase brake linings and have been confused by all the fancy high tech names and various cost differences? Or how about when you are having your brakes serviced and they rattle off all kinds of high tech brake lining names and various costs to go along with them? Here is what you need to know about brake linings:

There are all kinds of brake linings on the market. If you look at the typical chemistry in brake linings it is clear that there is a little bit of everything in them, therefore the manufacturer can call them just about anything they want. Say a particular manufacturer made a brake lining containing (pp):

20% BASO4 (Barytes)
15% oil modified phenolic resin
10% coarse synthetic graphite
10% fine natural graphite
10% steel fiber
10% aramid fiber (Kevlar)
10% vermiculite
5% copper fiber
4% reground rubber powder
3% ceramic fiber
1.5% carbon fiber
1% petroleum coke
0.5% fine silicon

Based on the following ingredients is would be correct is the manufacturer called it a **Non Asbestos Organic Friction Material (NAO)** because it doesn't have asbestos and it uses organic resin.

Semi-Metallic friction material because it has 10% steel and a strong magnet might stick to it and it has a metallic shine.

Low-Metallic friction material because it only has 10% steel and 10% doesn't seem like very much.

Cerami-Metallic friction material because it uses carbon fiber, graphite and steel

Corrector Lining because it has silica to clean and true the rotor.

Euro-Met because the term euro-metallic only vaguely refers to a bias for European performance and isn't adequately defined.

So as you can see the name that the manufacturer calls it doesn't really mean a whole lot. Often an aftermarket manufacturer will package brake linings and use the material description as a primary selling point. I prefer to see actual performance data on the particular lining I am considering using. If the manufacturer cannot or will not provide me that data then I will run my own performance tests in order to select the best lining for the specific application.

There is a wide variance in performance between various brake linings and formulations. In general, I prefer to stick with major brand name brake linings that have a reputation for quality and performance. Some of my personal favorites are Bosch and Bendix. In my opinion they produce excellent products and they are also a supplier for Original Equipment Manufacture (OEM) brake linings to the automotive manufacturers and must meet stringent manufacturers performance criteria as well as Federal Motor Vehicle Safety Standards (FMVSS) and utilize the same knowledge and technology used for the OEM components that they use for the aftermarket. Beware of low quality and low priced brake linings. This is not the place to attempt to save money and buy the lowest cost linings. Your vehicles braking performance and safety depend on them and they must function flawlessly and stop the vehicle effectively under all conditions. It is also important to note that although OEM supplied and installed brake linings must conform to strict FMVSS safety standards, aftermarket linings are not required to meet these specifications. That is just one more reason why I prefer to stick with major brand name brake linings manufactured by a company that supplies parts for production vehicles. There are also other several other manufacturers that do make quality brake linings (as well as private label them), however I recommend that you do your research and comparisons before making a purchase.

MAXIMIZING VEHICLE LONGEVITY

Over the last 30+ years of owning many different types of vehicles and equipment my main concern was always to determine how I could achieve the maximum performance and durability as well as significantly increase the longevity of the vehicle, far beyond what the manufacturer designed and tested the components and vehicle to last for. Here are a few of the many items that I found work very well in achieving this goal:

1. **Ball Joints**: these always seem to be a problem with me. Every single vehicle I have owned has required ball joints at a fairly low mileage. I become quite upset when I remove the OEM parts and find they are either frozen and do not move or are extremely loose. The failed ball joints resulted in sloppy or erratic steering, alignment problems and excessive tire wear. The problem I have found is that the original ball joints do not come with grease fittings. There are supposed to be “sealed for life”, however I find that is hardly the case. I do not replace them with the manufacturer’s parts because the same thing is bound to happen again. I have always purchased NAPA’s premium quality ball joints designed for severe duty fleet use that come with grease fittings. Since I began doing this on every vehicle I have never had another ball joint failure. I periodically grease the ball joints with AMSOIL Heavy-Duty Synthetic NLGI #2, GC/LB moly-based grease.

2. **U-Joints**: Most of today’s vehicles do not come equipped with grease fittings in the U-Joints of both front and rear driveshafts and front axle shafts on 4x4 trucks. I have also had a number of these “sealed for life” OEM units fail. The problem with them is not the grease inside failing but the seals letting dirt, water and other contaminants in which get inside the needle bearings and can eventually cause problems. I replace them with a premium quality U-Joint that has a grease fitting and have never had any failures since then. I keep them greased regularly with AMSOIL Synthetic Multi Purpose NLGI #2, GC/LB grease. I recently replaced the front axle U-Joints on one of my heavy-duty 4x4 trucks and was told that for that size of U-joint that the original manufacturer does not make one with a grease fitting. I went to my local NAPA auto parts and they had the U-Joints available with grease fittings, which I purchased and installed.

3. **Rust and Corrosion Protection**: Today’s cars and trucks offer much improved sheet metal and chassis component rust protection that older vehicles, however for myself it is still not good enough. I take every one of my trucks to Texaco Rustproofing to be coated. This is a very specialized material. It is very thick and gooey and must be heated in order to be applied with special pumping and spray equipment. It is applied at approximately 1/8-1/4 inch thickness on the entire underside of the vehicle as well as inside all doors

and sheet metal panels. It does not harden, crack and fall off over time like other competitive products do that I have tested. It develops a "skin" on the surface but the product under the skin remains relatively soft and pliable. On extremely hot summer days it can sometimes ooze out of panels which is not a problem as there is plenty of product thereto prevent corrosion that stays in place, however it is very important to take a screwdriver and make sure the drain holes at the bottom of doors and tailgates are not plugged or they will retain water inside.

4. **Shock Absorbers**: I have also had just about every OEM shock absorber fail at a relatively early age. I replace them with premium quality aftermarket shock absorbers and get much better performance and longevity. Recently on one of my heavy-duty diesel trucks I was wearing flat spots all around the center of my front tires. What I determined was happening is that the tires were leaving the road surface and upon re-contact with the road eventually wore these flat spots on the tires. The factory shocks were not strong enough to effectively keep the tires on the road. I installed an aftermarket dual shock kit with heavy duty gas charged off road shocks and Centramatic (www.centramatic.com) automatic wheel balancers and immediately solved the problem. One would think the manufacturer would have figured this out. My 1987 lighter duty 4x4 trucks came factory equipped with dual front shocks while my 1999 and 2006 heavy duty 4x4 trucks with an extremely heavy diesel engine option came with only single front shocks.

5. **Exhaust Systems**: The exhaust system of every truck I own has been replaced with a premium quality stainless steel aftermarket performance exhaust system. I noticed improved fuel economy, increased horsepower and torque, lower exhaust gas temperatures, reduced exhaust backpressure and much faster response for the turbochargers on the diesel trucks. The time it took to achieve higher turbo boost levels was reduced. I also noticed much more power when towing heavy loads.

6. **Coolant Filtration:** I have installed coolant filtration kits on my diesel trucks. The coolant filters remove and dirt particulates or scale that accumulates and can cause heat transfer and reduced flow problems as well as potential water pump failure. When I take off a used coolant filter, drain it and let it dry over a period of time and then cut it open I am amazed at the amount of particulates it has trapped.

7. **Synthetic Lubrication:** Every single truck and piece of equipment I own uses premium quality AMSOIL synthetic lubricants throughout. **This is by far the single most important and beneficial item in achieving maximum performance and longevity of these vehicles**. Synthetic lubricants are available for engines, transmissions, differentials, transfer cases, steering and suspension components and any other component or system that requires lubrication. As documented in this book, synthetic lubrication is far superior to petroleum based lubrication and has been proven to drastically reduce wear as well as increase performance under all conditions, increase fuel economy and save significant amounts of time and money in the process. Just because a person uses petroleum oil and changes it often does not mean that they will get anywhere near the protection a premium quality synthetic oil provides. They may feel good because they think they are doing something beneficial by constantly changing the petroleum oil,

however they could be doing a lot less work and saving money in the process while providing superior protection for the vehicle.

8. **Superior Filtration**: Effective air, oil and fuel filtration, as discussed in this book, are critical to achieving maximum performance and longevity for your vehicle. I personally utilize AMSOIL Absolute Efficiency nanofiber technology air filters and by-pass oil filtration systems on every truck I own and attribute my vehicles incredible longevity and performance to these systems. Do not attempt to save money by purchasing low cost filtration products. The old adage "you get what you pay for" is especially true here. The lubricants you select along with the filtration products and systems all work together to provide maximum protection. Any one of them that does not meet superior performance criteria can compromise protection.

9. **Nickel Anti-Seize:** I have found that this product, manufactured by Loctite Corp., provides exceptional corrosion, seizing and galling protection for an extremely long period of time. Use it on fasteners to prevent corrosion and allow for uniform clamp loading, mating parts to prevent corrosion and allow for ease of disassembly in the future, exhaust system fasteners, and just about any other application where severe duty corrosion protection is required as well as under extreme pressure and temperature conditions up to 2400 deg. F. This product is superior to anti-seize products that do not have nickel. The nickel is sub-microscopic and will get in the valleys of the machined surface profile of mating components and allow for metal-to-metal contact while still providing superior corrosion protection.

10. **Quality Fuels**: There is a wide difference in the quality of both gasoline and diesel fuels, which can have an important effect on the performance and longevity of your vehicles. Sure, your vehicle will operate with any fuel, however it is a matter if you want optimum or average performance and benefits. When it comes to fuels, you get exactly what you pay for and there is a reason why certain fuels are much lower cost than others. This doesn't mean that you need to use a premium fuel, just that you need to find a quality fuel at a reasonable price. Additionally people that own vehicles with diesel engines are now using Ultra Low Sulfur Diesel Fuel (ULSD) which has had sulfur, a necessary lubricant, reduced from 500 ppm to 15 ppm as mandated by the EPA. It is recommended that diesel vehicle owners to use an aftermarket Diesel Fuel Performance and Cetane Boost Additive to compensate for the reduced lubricity in ULSD. There are ASTM test labs that can perform tests on fuels to determine their quality level and I have had these tests performed on the fuels that I regularly use in addition to using the Fitch Fuel Catalyst (www.fitchfuelcatalyst.com) on all my vehicles and equipment. The Fitch Fuel Catalyst improves fuel at the molecular level for optimum power and performance.

I hope that this section has helped you to understand that there are many things you can do to increase the performance and longevity of your vehicle. The preceding items are only a small sampling of some of the more important items. I am here to help anytime you have questions and thank you for reading my book.

Special Bonus Section

Dave Mann,
Lubrication Specialist – Truck/Automotive Engineer
Motor Oil Engineers, L.L.C.

Email author with any questions: dave@performanceoiltechnology.com

Appendix A- References

Please note that I have a Bachelors of Science Degree in Automotive Engineering combined with a career of extensive experience in the Automotive Industry covering all facets of both Automotive and Truck Engineering, Development and Testing and Component and Systems Engineering, Development and Testing, therefore much of the material in this book is from personal and common industry knowledge gained during those years, as well as my oil business experience, supplemented by specific references listed below where applicable. Dave Mann

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