Oil and the Modern Harley-Davidson® Motorcycle

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Foreword

Saint Augustin wrote: “For what is time? Who can easily and briefly explain it? Who even in thought can comprehend it, even to the pronouncing of a word concerning it?” (Schaff, 1886).

I was struck by this quote as I began to organize my thoughts for this article. It parallels some of my own questions about this strange fluid. When asked to describe what oil does and why a particular brand or type is better, people seem to be at a loss for words. We often revert to parroting the last thing we heard that was believable. Do we really know anything or are all of our decisions really the results of someone’s marketing scheme? In other words, is the oil we use really “better” than the other we do not?

In order to help you understand some of the things that go into answering such questions I’ll start with oil basics. We’ll go over what oil is, what it is not, how it’s made and why and how oil in the stores is graded. It will do no good to tell you that you need grade “KY” oil if you have no idea how to find one. I’ll also answer some basic questions such as the differences between motorcycle and automotive oils, the differences between oils sold for transmissions and the engine, how often you should change your oil and other important discussions.

Be forewarned though; there will be no “perfect” oil named. You cannot skip to the last page of this article to get the answer you need. It’s all about choices and I’ll give you information to help you make them.

What is Oil?

Oil and its cousin natural gas make up what we call “petroleum”. The word roughly translated from its Latin roots means “rock oil” (Houghton Miffin, 2000). This proves what I’ve known all along; motorcycles and Rock and Roll go together.

Motor oil is made up of base stock plus additives. The sheer number of different types of additives and their properties virtually guarantee that there is no single oil that’s perfect for every application.

Base Stock

Base oil is the plain oil, either synthetic or petroleum based, with which an oil company mixes various compounds to create the finished product. The percentage of base stock that’s in your quart of oil varies but a common number used for discussion purposes is a quart of oil is made up of 70% base stock.

Base stock has several properties that contribute to the finished product. At its simplest level we can break base stock down to synthetic versus petroleum.

Petroleum

In 1852 the first petroleum based oils became available. Until that time, animal-based oils were used for lubrication. First, lubrication suppliers learned which crude oils made the best lubricants. Soon after, distillation was employed to refine that crude oil. Beginning in the 1920’s, lubrication manufacturers began processing these base stocks to improve performance. Some methods used in the “dark ages” of the oil industry were clay treatment, acid treatment, SO_2 treatment, and finally solvent treatment.

Approximately two-thirds of the petroleum base stock in the U.S. is manufactured using solvent refinement. These Group I oils have >10% aromatics and more than 300 ppm sulfur. The process is two-phased: aromatics are removed by solvent extraction; wax is removed by chilling (Kramer, D. C., Lok, B. K., Krug, R. R., 2001).

Group II base oils are created and refined with hydrocracking and early wax isomerization technologies. These contain lower levels of impurities (<10% aromatics, <300 ppm sulfur), they also are almost colorless. From a performance standpoint, improved purity means that the base oil and the additives in the finished product can last much longer (Kramer, D. C., Lok, B. K., Krug, R. R., 2001).

Synthetic

Try to research why synthetic oils are better and 99% of what you will find is why “X” synthetic oil is better. Try it, I dare you! Once you wade through a few pages of web searches with propaganda, try excluding a certain brand name from your search and see how much easier it is. Such is the problem with trying to get real information about oil. The Internet has played a huge role in the dissemination of information but it also allows every instant “oil engineer” to spout rhetoric about oil that is slanted at best and can be wrong at worst.

Synthetic oils are the subject of much discussion, some rumor, and some outright lies. The infamous “bearing skate” is one such lie. Nobody really knows who started this FUD (Fear, Uncertainty, Doubt) campaign but they must be very proud of themselves. In the “it’s better to be safe than sorry” camp are people who simply never used synthetic oils because of these doubts propagated by companies because they didn’t have their own synthetic to sell. Think about this bearing skate thing for a moment. You have a roller or ball bearing that supposedly is so well lubricated, so devoid of all friction, that it does not roll. Since it does not roll it plows through the oil film and “skates” on the journal and wears the bearing and journal. If there’s not enough friction to turn the bearing, how in the world is it supposed to wear the bearing?

Another common story about synthetic is that it causes leaks. This one may have some basis in fact. Synthetic oil is polarized; it has a negative end chain, iron and steel have a positive end chain. Oil is attracted to bare surfaces and is trying to spread to cover all surfaces. If you have a weak gasket, a good synthetic oil will capillary or migrate through it because it wants to cover bare metal. That is actually one of the key advantages to synthetic oil. So yes, it might leak through areas that never leaked before but it's because of all the properties that we want in the oil.

The intelligent reader may be wondering at this point, “why use synthetic?” There are several good reasons to use it. One is heat stability. All oils are different, some behave differently to heat. You may have seen the difference between butter and vegetable oil in a frying pan. Under heat, the butter will darken and burn while at the same temperature, vegetable oil will do just fine. A synthetic is similar to the vegetable oil – it is more stable under extreme heat.

Another heat-related benefit is the volatility and chain length. Generally, shorter chain molecules are more volatile. Under heat, these oil components volatize or gas off, much like water boils, and leave the oil. This causes the viscosity to change among other things. A synthetic oil has less of these short chain elements. Because it is created rather than refined, the molecules are more uniform in length.

Not everyone needs or wants the advantages synthetic oil offers. For those that do there is a wide variety available. Even within the classification of synthetic oils, there are different “flavors.” Here we will discuss several:

PAO

Most synthetic oils are created with a base stock of polyalphaolefin (PAO). The synthesizing of PAO starts with ethylene gas, a simple two-carbon molecule, and builds upon that molecule till it forms a 10-carbon molecule. Three of those larger molecules are then combined to form PAO. The result is a fluid more stable than the usual base oils derived from crude. It keeps flowing at low temperatures, is more resistant to boiling off, and more resistant to oxidation, which causes thickening with prolonged exposure to high temperatures (Bedard, 2000).

POLYESTER

Another type of base stock used in synthetic oils is ester based (diester, polyolesters, polyesters, and complex esters). These have been tested as extremely stable under high pressures and temperatures and provide the base for oils used in some jet engines. The high end of the temperature range for these oils is 400ºF, well above the typical oil temperatures in an air cooled engine of 200ºF to 250ºF. Ester-based oils are also polar, meaning they have an electo-chemical charge that causes them to bond to metal surfaces (Wolman, n.d.). Whether this actually helps or not is a subject of some dispute.

OLEAN?

Polyesters are synthetic resins put most simply. Even though technically polyester, a new food product has seen some interest by the Air Force as a potential for a high temperature, broad range lubricant. What is that product? Olean™ brand of olestra. Olean is a sucrose octaester used in foods as a fat substitute. If the biological effects of eating too many Olean-based potato chips are any indication, it’s some slippery stuff indeed. In an experiment where the oil was held at 426°F for nine hours, a sample based on Olean maintained 70% of its mass over the course of the test while their current oil used in jet engines lost 90% (Blanski, n.d.). I'm sure it's a long time before we'll be able to squeeze out a bag of potato chips and use it as oil, but it's interesting and scary, all at the same time.

"New" Synthetic

It couldn't be simple could it? We had it easy; either oil was mineral based or synthetic. Nothing that simple could last; it was an area obviously ripe for exploitation. In 1984 Chevron successfully combined several processes to remove aromatics (generally lighter products) and waxes (generally heavier products) from fossil oil. These processes combined were referred to as "hydroisomerization" (Kramer et al., 2001). The 'hydro" in this case refers to the hydrogen used in the process. Isomerization is the process where the atoms that make up a molecule are changed around to make a similar molecule with different properties (Houghton Miffin, 2000).

What the hell does that mean? Synthetic oil is superior in part because of the uniform shape and size of the molecules. This hydroisomerization process removes waxes and aromatics to a greater degree than other refinement methods. It also changes some of the molecules to be slightly different, enhancing resistance to oxidization. In effect it makes petroleum oil base more like synthetic.

Intelligent folks at this point will be thinking that this is still petroleum oil, right? Hamburger is still beef, isn't it? Well yes (the beef part) and no (the oil part). The National Advertising Division (NAD) of the Council of Better Business Bureaus is often responsible for arbitrating between feuding advertisers on their conflicting claims. When Castrol began to use this hydroisomerized base in its Syntec line, Mobil Oil took them to task for deceptive advertising. In April of 1999 the NAD decided in Castrol's favor regarding the labeling of oil created from this type of base stock:

> The NAD determined that the evidence presented by the advertiser constitutes a reasonable basis for the claim that Castrol Syntec, as currently formulated, is a synthetic motor oil. […] NAD noted that the action taken by the SAE to delete any reference to "synthetic" in its description of basestocks in section J354 and API's consequent removal of any mention of "synthetic" in API1509 were decisions by the industry not to restrict use of the term "synthetic" to the definition now proffered by Mobil. Further, the SAE Automotive Lubricants Reference Book, an extensively peer-reviewed publication, states base oils made through the processes used to create Shell's hydroisomerized basestock, severe cracking, and reforming processes may be marketed as "synthetic" (Bui, 1999, A defining moment for synthetics, ¶ 6).

What does that all mean? It means that a company may create synthetic oil with mineral based stocks and market it correctly as fully synthetic oil. When asked if this reduction in cost for the production of their synthetic stock would result in a reduction of cost to the consumer, the answer from Castrol was “no” (Bedard, 2000).

Additives

Additives began to be widely used in 1947 when the American Petroleum Institute (API) began classifying engine oils by severity of service: regular, premium, heavy-duty. Regular oils had no additives and were intended for under 100 hours of mild use. Premium oils had some additives to extend the life of oils used in passenger cars. Heavy-duty oils had the most additives and were intended for commercial trucks and construction equipment (Kramer, D. C., Lok, B. K., Krug, R. R., 2001).

In the 1950’s, multigrade oils were introduced that had polymers added to enhance the viscosity index, a measure of the useable temperature range of the oil. Since then, oil improved only as additives improved. This was the only way to make a better oil, until new base oil technology became available (Kramer, D. C., Lok, B. K., Krug, R. R., 2001).

As the API classifications evolve, different additive packages must, by necessity, evolve with them. As oils change from SJ to SL and to the newest: SM, the additive packages are different. The Bob’s Brand grade SJ you used last year is not the same as the Bob’s Brand grade SL you are using this year, even though the packaging may be the same.

Anti-Wear Additives

The prime additives for anti-wear properties are zinc and phosphorous. These are typically added in the form of zinc dialkyldithophosphate (ZDDP). The zinc level was typically 0.12% to 0.15% in SG automobile oils; some SL oils now have as little as 0.05%. This is not necessarily a bad thing in and of itself, oil manufacturers are using other additive packages these days to provide anti-wear properties in their oil (DiCarlo , 1999). Other anti-wear additives used are molybdenum, manganese, potassium, and sodium. Molybdenum is such a hot topic that we’ll talk about that separately later on. ZDDP is a last resort protection against metal-to-metal contact. Motorcycles are no more prone to metal-to-metal contact than automotive engines. Improved viscosity maintaining compounds reduce the possibilities that this will be an issue (Guillory, 2002).

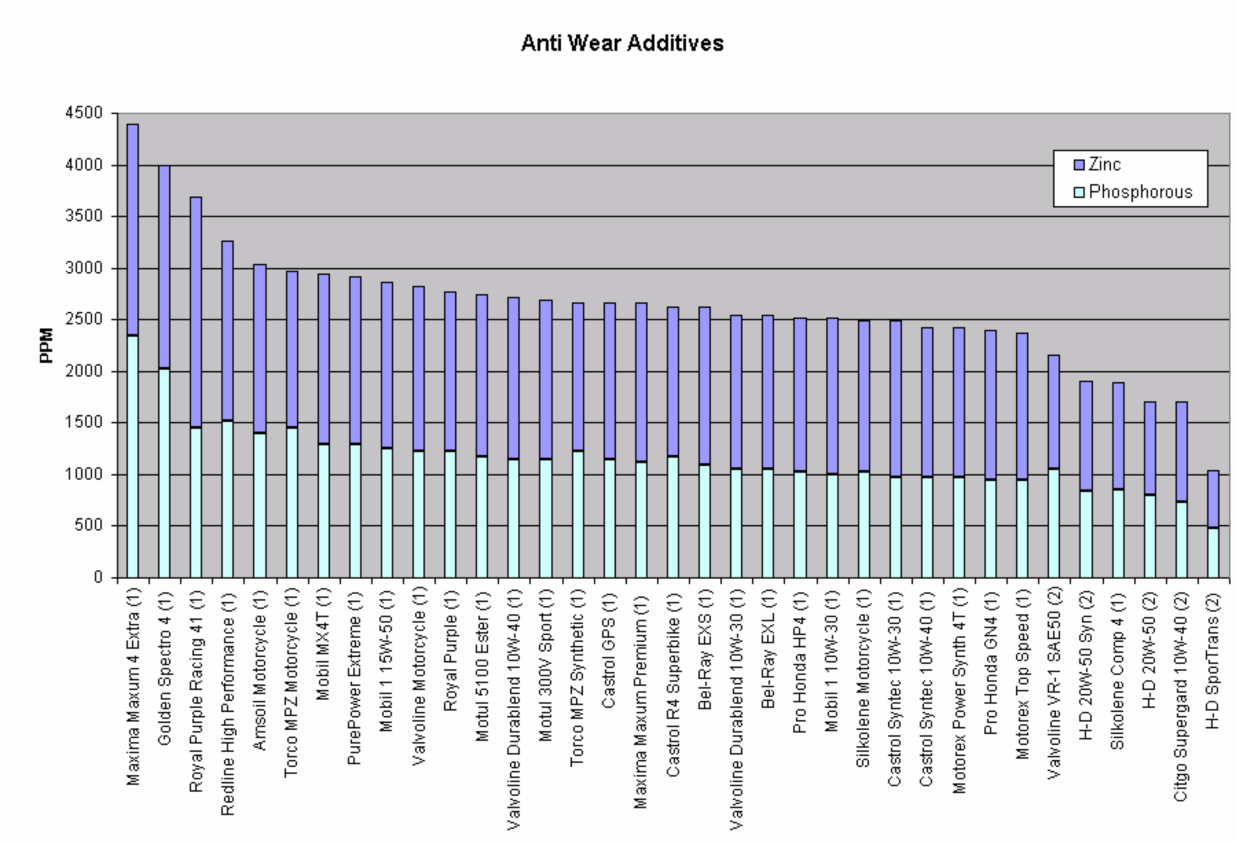


Figure 1. A comparison of anti-wear additives in motor oils.

(1) Note. From Motorcycle Consumer News, Oil Investigation Update. 2003

(2) Note. From Blackstone Labs, solicited testing. 2004

Why the changes? The Environmental Protection Agency (EPA) wants them of course. Some oil is burned during normal engine operation from PCV vapors re-entering the intake flow, from oil that travels down the intake and exhaust valves, and from oil that coats the cylinder walls. Anti-wear additives, such as zinc and phosphorous, harm catalytic converters by polluting the catalyst and reducing its effectiveness. The reduction in phosphorous specified for SJ grades was only specified for oil viscosity of 0W-20 through 10W-30 however; the heavier oils are not restricted by this reduction requirement (DiCarlo, 1999). Additives do cost the oil companies money though, if they can get by with less, they probably will. There's also value in them standardizing their additive packages, simplifying production and lowering R&D costs.

Molybdenum

Molybdenum, or "moly", is an anti-wear compound added to oils in the form of molybdenum disulfide. Its use is controversial in motorcycles, fabled to be one of the scurrilous "friction modifiers" that destroys clutches. Across the industry, the consensus is to avoid oils containing moly. It seems a safe position to take, although no concrete evidence exists that I can find. Indeed, several members of the Sportster Internet community have used these "dangerous" oils for extended periods of time including severe (land speed record racing) duty with no reported issues (G. Crim, personal communication).

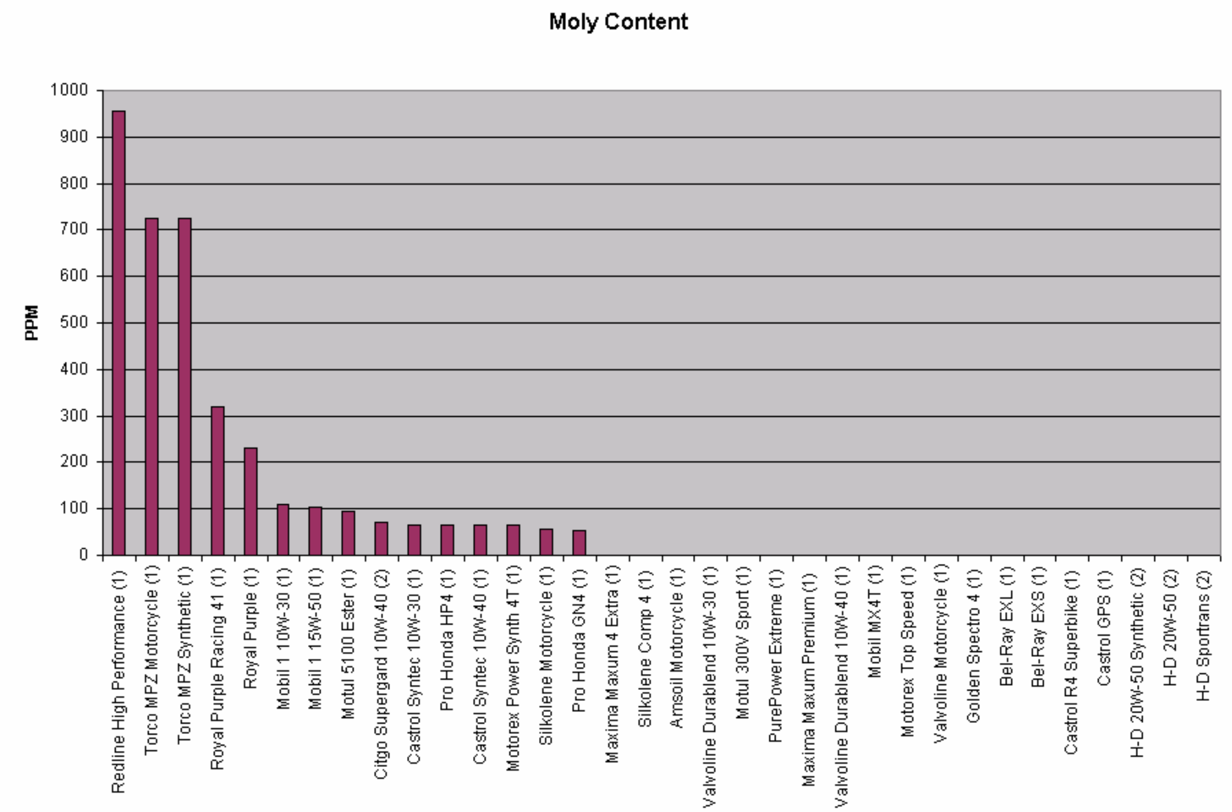


Figure 2. A comparison of molybdenum content in motor oils.

(1) Note. From *Motorcycle Consumer News, Oil Investigation Update*. 2003

(2) Note. From *Blackstone Labs, solicited testing*. 2004

A reasonable question, given advice to avoid moly, is how to figure out what oils contain molybdenum (Fig. 2). Additive packages are typically not divulged by manufacturers. Oil can be tested to determine the major constituents of the additive package; however this is far from convenient when you need oil now. The prepared owner will either plan ahead, or simply purchase the oil specified by the manufacturer.

Acid Neutralizers

Sulfur is present in gasoline. When burned, this sulfur can combine with oxygen to form sulfur dioxide, or sulfuric acid. This is pretty much a bad thing for any engine, you don’t want it. Oil manufacturers add compounds that neutralize this acid much like taking an antacid does for your stomach. Some of the more common compounds added to oil to neutralize acids are boron, calcium, and magnesium (Fig. 3).

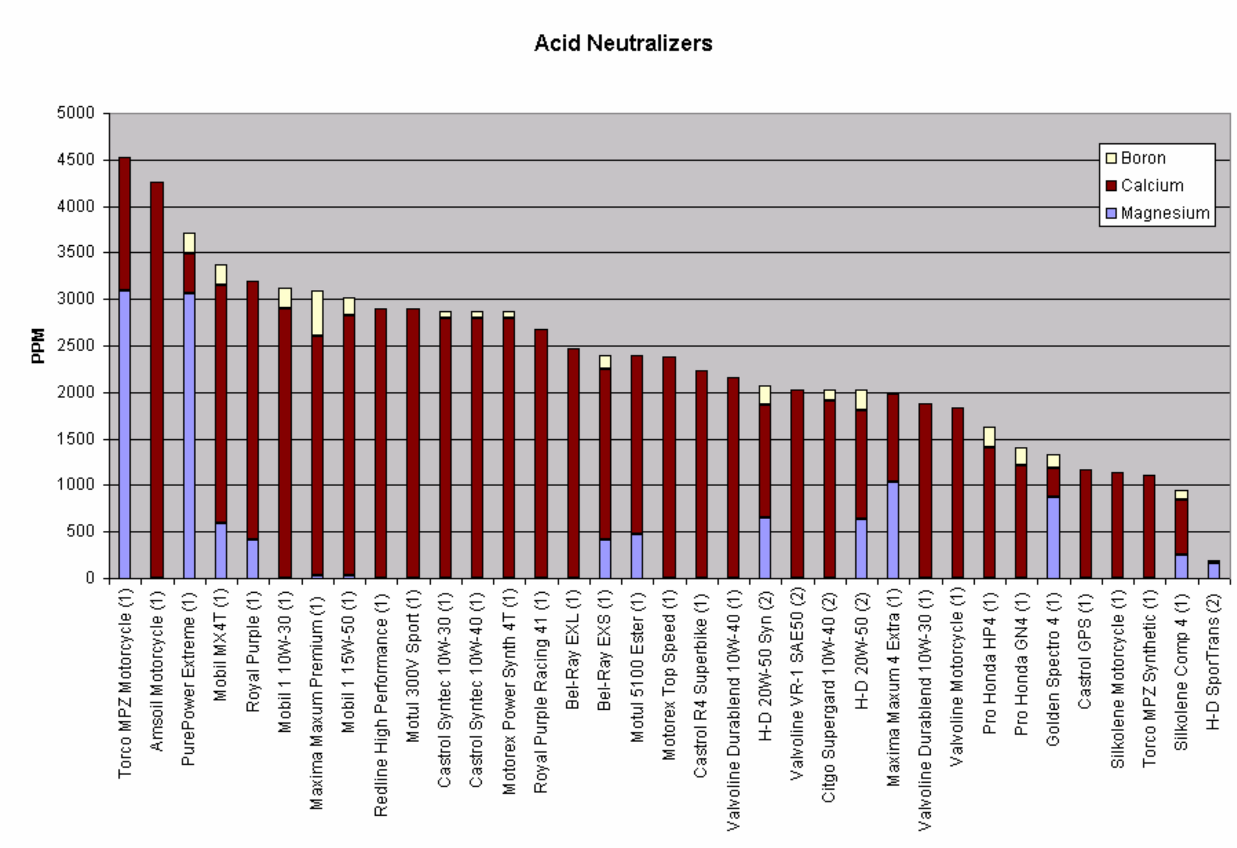


Figure 3. A comparison of acid neutralizing compounds in motor oils.

(1) Note. From *Motorcycle Consumer News, Oil Investigation Update*. 2003

(2) Note. From *Blackstone Labs, solicited testing*. 2004

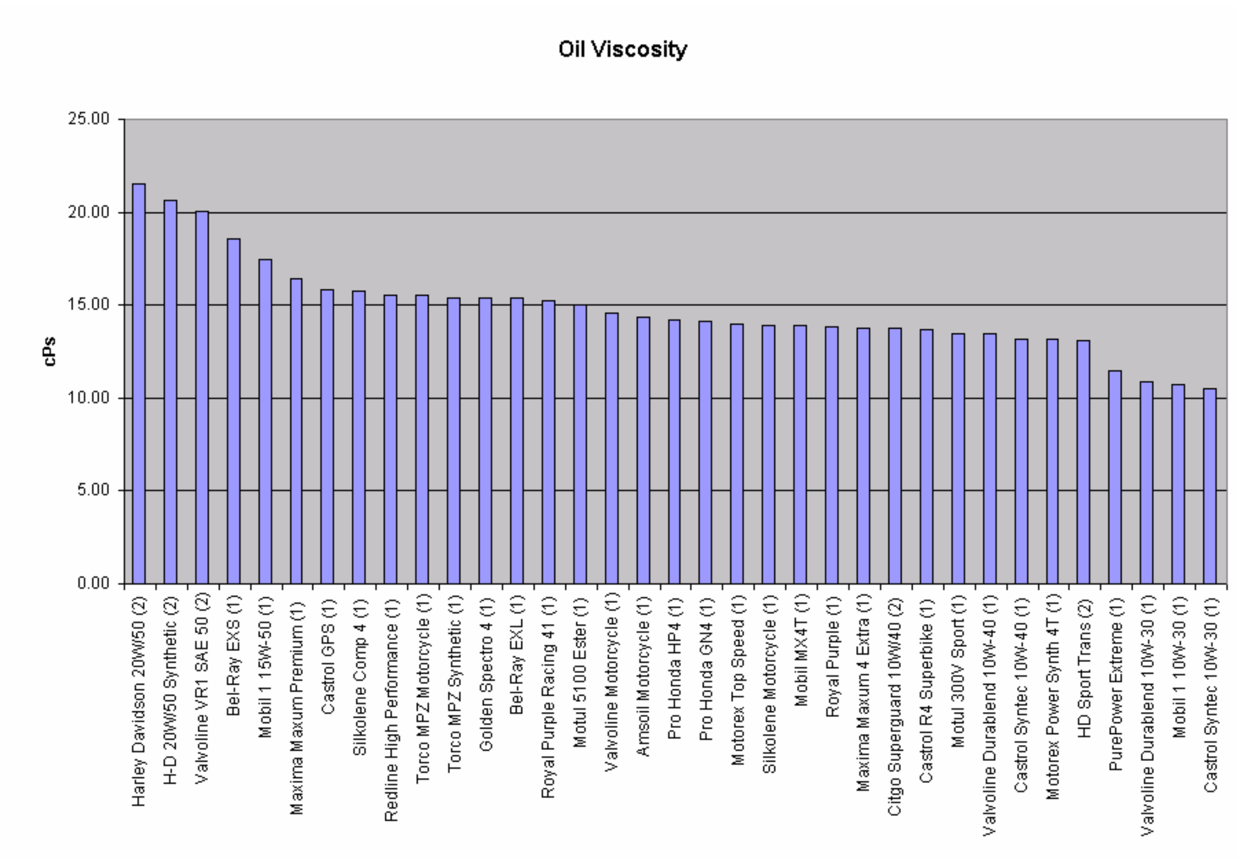
The amount of these additives is measured in parts per million, or ppm. When you get oil tested you get an indication of the level of these additives. The problem is, the levels in ppm do not give any indication of the potential to neutralize acids – also known as reserve alkalinity. This is measured in TBN or Total Base Number. As the oil absorbs and neutralizes acids, this number drops. A good oil analysis will indicate this number and when it's time to change oil. Oil with a higher TBN when new can be assumed to have a higher acid neutralizing potential (U.S. Oil Co., Inc., (2005).

Oil Classifications

Two bodies within the U.S., the Society of Automotive Engineers (SAE), and the American Petroleum Institute (API), are responsible for the classification system American Engine manufacturers' reference when specifying oils to be used in engines. These detail the weight, performance level, and energy saving characteristics of the oil.

Viscosity

Oil's viscosity is an arbitrary measurement that defines oil's ability to flow through a metered hole at a given temperature. A lower number means the oil flows quicker, implying "thinner" oil. These measurements are standardized in tests detailed by the SAE.



<u>Figure 4.</u> A comparison of tested viscosity of motor oils.

(1) Note. From *Motorcycle Consumer News, Oil Investigation Update*. 2003

(2) Note. From *Blackstone Labs, solicited testing*. 2004

Viscosity is the "pillow" that protects moving parts in your engine. To understand how it is important, it is important to understand the types of bearings in use in your engine. Bearings are classified as sliding surface (friction) or rolling contact (anti-friction) types. Oversimplified, there are two main types, journal bearings and roller/ball bearings. A journal bearing, sometimes called a sleeve bearing, is a soft metal shell that is made to wrap around a flat journal surface; there are no moving parts to the bearing. A thrust bearing is a close relative to the journal bearing, a thrust bearing lines a thrust surface in an engine. Roller or ball bearings use roller or ball bearings, commonly contained in a cage, running in a race or journal. No matter the bearing type, the two parts do not actually touch each other; they ride on a thin layer of lubricant (Bearings and Seals, 2003).

A journal or thrust bearing (such as found supporting the cams in a Sportster™ motor) requires oil pressure to maintain the cushion of oil on which the surfaces slide. A rolling bearing (such as the crank and rod journal bearings in a Harley-Davidson® motor) requires oil flow to make sure that the rollers never touch the bearing surface, and that heat is carried away. One can see that it is very difficult to build up pressure feeding a rolling bearing. For this reason, the viscosity is to a greater extent than oil pressure, vital for the health of a Harley-Davidson® motor. Not enough viscosity and the rolling bearings will make contact with their races, but too much and there will not be enough oil flowing to the journal bearings to keep them floating. This is why any changes from the manufacturer's recommendations for viscosity should not be taken lightly.

Some oils are multi-grade and some a single or "straight" grade. When oil is advertised as a 20w-50 for example, it is considered a multi-grade. A single or straight grade is indicated as a

50 or sometimes SAE-50. The “w” after oil’s viscosity rating means that the viscosity was measured at 0º F; no letter indicates that the oil was measured at 212º F. In the case of a 20w-50 we can see that the oil exhibits the characteristics of 20 weight oil at 0º F while having the properties of 50 weight oil at 212º F. This does not mean that the oil is thicker as it gets hotter; merely that it takes on different properties:

> Multi viscosity oils work like this: Polymers are added to a light base (5W, 10W, 20W), which prevent the oil from thinning as much as it warms up. At cold temperatures the polymers are coiled up and allow the oil to flow as their low numbers indicate. As the oil warms up the polymers begin to unwind into long chains that prevent the oil from thinning as much as it normally would. The result is that at 100 degrees C the oil has thinned only as much as the higher viscosity number indicates. Another way of looking at multi-vis oils is to think of a 20W-50 as a 20 weight oil that will not thin more than a 50 weight would when hot (Hackett, n.d., More than you ever wanted to know about motor oil, ¶6).

Sometimes people advise to only use straight weight oil, this is typical for older motors. The reason for this is that the motors were designed with a single viscosity in mind and the clearances and other parameters were designed with these considerations. Using multi-weight oil can have some consequences (good or bad) on such motors, as can using straight weight on multi-grade rated motors. In other words, straight 50 weight oil is thicker at cooler temperatures than 20W-50. If the engine is cold, the thinner oil of the multi-grade may go places you don’t want – like the garage floor. Conversely, using a straight grade in a multi-grade motor may restrict oil from places it needs to go when the motor is cold. You should only change from the viscosity recommended by the engine maker if you understand the reasons for changing and the potential repercussions.

Just in case you've begun to feel comfortable about your grasp of the rating system; allow me to throw a wrench in the works. Oil that is tested and rated to be a 20W-50 may be marketed as straight 50 weight oil because there are no other tests required for straight weight oil. A few synthetic oils that are marketed as straight-grade oils exhibit properties of a multi-grade without the polymeric thickeners that other oils use. If you really want to run or need straight weight oil, it's possible that a synthetic may not be your best choice. It could not be easy could it?

API Service Grades

For automotive gasoline engines, the latest engine oil service category includes the performance properties of each earlier category. If an automotive owner's manual calls for SJ or SL oil, SM oil will provide full protection. For diesel engines; the latest category usually, but not always, includes the performance properties of an earlier category.

GASOLINE ENGINES

Gasoline engine oil categories are for cars, vans, and light trucks with gasoline engines. These oils, designed for gasoline-engine service, fall under API's "S" (Service) categories.

Category	**Status**	**Service**
SM	Current	For all automotive engines currently in use. Introduced November 30, 2004, SM oils are designed to provide improved oxidation resistance, improved deposit protection, better wear protection, and better low-temperature performance over the life of the oil. Some SM oils may also meet the latest ILSAC specification and/or qualify as Energy Conserving.
SL	Current	For 2004 and older automotive engines.
SJ	Current	For 2001 and older automotive engines.
SH	Obsolete	For 1996 and older engines. Valid when preceded by current C categories.
SG	Obsolete	For 1993 and older engines.

SF	Obsolete	For 1988 and older engines.
SE	Obsolete	CAUTION—Not suitable for use in gasoline-powered automotive engines built after 1979.
SD	Obsolete	CAUTION—Not suitable for use in gasoline-powered automotive engines built after 1971. Use in more modern engines may cause unsatisfactory performance or equipment harm.
SC	Obsolete	CAUTION—Not suitable for use in gasoline-powered automotive engines built after 1967. Use in more modern engines may cause unsatisfactory performance or equipment harm.
SB	Obsolete	CAUTION—Not suitable for use in gasoline-powered automotive engines built after 1963. Use in more modern engines may cause unsatisfactory performance or equipment harm.
SA	Obsolete	CAUTION—Contains no additives. Not suitable for use in gasoline-powered automotive engines built after 1930. Use in modern engines may cause unsatisfactory engine performance or equipment harm.
Note: API intentionally omitted "SI" and "SK" from the sequence of categories.		

Figure 5. Gasoline engine motor oil grades.

Note. From *American Petroleum Institute, Motor oil guide. 2004 ed.*

DIESEL ENGINES

Diesel engine oil categories (for heavy-duty trucks and vehicles with diesel engines): Oils designed for diesel-engine service fall under API's "C" (Commercial) categories.

Category	**Status**	**Service**
CI-4	Current	Introduced in 2002. For high-speed, four-stroke engines designed to meet 2004 exhaust emission standards implemented in 2002. CI-4 oils are formulated to sustain engine durability where exhaust gas recirculation (EGR) is used and are intended for use with diesel fuels ranging in sulfur content up to 0.5% weight. Can be used in place of CD, CE, CF-4, CG-4, and CH-4 oils. Some CI-4 oils may also qualify for the CI-4 PLUS designation.
CH-4	Current	Introduced in 1998. For high-speed, four-stroke engines designed to meet 1998 exhaust emission standards. CH-4 oils are specifically compounded for use with diesel fuels ranging in sulfur content up to 0.5% weight. Can be used in place of CD, CE, CF-4, and CG-4 oils.
CG-4	Current	Introduced in 1995. For severe duty, high-speed, four-stroke

		engines using fuel with less than 0.5% weight sulfur. CG-4 oils are required for engines meeting 1994 emission standards. Can be used in place of CD, CE, and CF-4 oils.
CF-4	Current	Introduced in 1990. For high-speed, four-stroke, naturally aspirated and turbocharged engines. Can be used in place of CD and CE oils.
CF-2	Current	Introduced in 1994. For severe duty, two-stroke cycle engines. Can be used in place of CD-II oils.
CF	Current	Introduced in 1994. For off-road, indirect injected and other diesel engines including those using fuel with over 0.5% weight sulfur. Can be used in place of CD oils.
CE	Obsolete	Introduced in 1985. For high-speed, four-stroke, naturally aspirated and turbocharged engines. Can be used in place of CC and CD oils.
CD-II	Obsolete	Introduced in 1985. For two-stroke cycle engines.
CD	Obsolete	Introduced in 1955. For certain naturally aspirated and turbocharged engines.
CC	Obsolete	CAUTION—Not suitable for use in diesel-powered engines built after 1990.
CB	Obsolete	CAUTION—Not suitable for use in diesel-powered engines built after 1961.
CA	Obsolete	CAUTION—Not suitable for use in diesel-powered engines built after 1959.

Figure 6. Diesel engine motor oil grades.

Note. From *American Petroleum Institute, Motor oil guide. 2004 ed.*

Regular vs. Motorcycle Oils

It's time for the big question: "Are automotive oils and motorcycle oils different?" The easy answer is "yes they are." In tests that I've had performed, and in tests that I have seen reported, there is a difference in some of the oils. The problem here is that a difference in formula does not necessarily imply a difference in requirements. For instance, say Bob's Auto Oil has 0.05% ZDDP, and Bob's Motorcycle Oil has 0.02% ZDDP. Sure enough, in this case the motorcycle oil is not like the automotive oil. The problem here is Steve's Motorcycle Oil may have 0.07% ZDDP. Just because Bob has a "special" motorcycle oil does not necessarily make it better.

Tests done by Motorcycle Consumer News indicated that there were substantial similarities in automotive and motorcycle offerings in many brands (Fig. 1, 2, 3). You could tell the difference, but the basic trends were the same with regards to additives. Most recently, I have people writing me telling me that their new motorcycle oil is reformulated and nothing like their car oil. Well that's nice and all, I'm sure it's different from their car oil, but what if it's just like someone else's car oil now? Until they tell me exactly what the changes are I cannot, make a decision as an informed consumer.

One area that might bear some fruit is oil's ability to resist heat aging. All petroleum products have volatile compounds that will gas off, as well as others that will oxidize. It seems reasonable to believe that in some parts of a bike's engine, the oil will experience higher temperatures than it would in a water cooled automotive motor. Aside from differences between synthetics and petroleum oils, there are no notable difference between motorcycle and automotive oils. One can either infer from this that heat aging is not a concern, or that there's nothing that can be done within the blends' parameters to significantly change this characteristic.

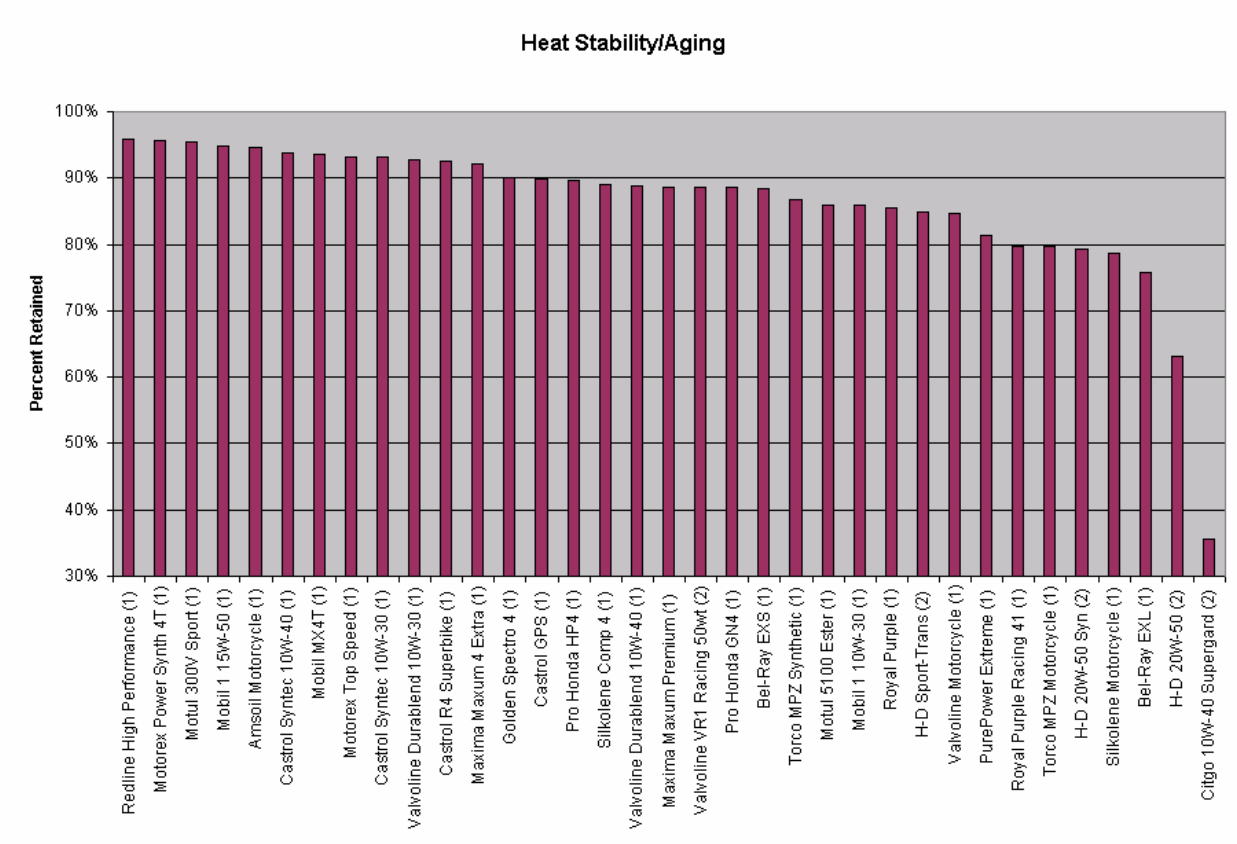


Figure 7. A comparison of heat stability and aging properties of motor oils.

(1) Note. From *Motorcycle Consumer News, Oil Investigation Update*. 2003

(2) Note. From *Alven, solicited testing*. 2004

It should be noted, as you review the testing results provided (Fig. 7), that the heat stability testing done for our report were not according to a specific ASTM test procedure. While most of the results were consistent with the earlier test results and therefore potentially informative for comparison purposes, some significant deviations were noted. Additional testing had been planned but was not completed as of the date of this publication.

Most oil manufacturers and marketing departments will throw results of “independent tests” at you. At least one oil manufacturer I know of has a financial arrangement with their “independent” testing lab; if I know about them there has to be more I don’t know about. I’ve said it before: you have to be informed to make a decision. If the manufacturers are not informing you about the changes, why in the world should you change to their product? If products are now “new and improved,” does that mean that the “old and ordinary” stuff you used last week hurt your engine? By far the easiest solution is to use what your motorcycle manufacturer recommends. If you choose to depart from this path, do so only because you know why you are doing it. Never change because of claims of reduced wear, better mileage, or cooler running engines. “Build a better mousetrap and the world will beat a path to your door” as they say. If there’s not a major engine manufacturer (not a racing team full of corporate whores) running to change, you probably should not either. Now if you want to do independent testing on any of this then by all means, let us know how it works out.

Crankcase vs. Transmission

Harley-Davidson® says to use it’s SYN3 in all three holes (two if you ride a Sportster). H-D also sells regular 20W-50 and Sport-Trans for the Sportster primary which shares its oil with the transmission. H-D also sells Primary Chaincase Lubricant, and Semi-Synthetic Trans Lube for Twin Cam™ motors. Why the differences? To make that determination we have to examine the differences between gear oils and engine oils.

Engine or crankcase oils have the responsibility to neutralize and carry away combustion by-products that get past the rings. To do this they have alkali-based products added that neutralize the acids that can form. Gear oils do not have this limitation and can use extreme pressure additives to help protect gear faces as they mesh into each other. Gear oils typically have sulfur-based additives to help with this protection where in an engine; these sulfur compounds would combine with moisture produced in the engine to form sulfuric acids.

If you choose to use compare gear and crankcase oils, you should know that the viscosity ratings are determined differently for each. The numbers given, without getting too technical and boring, are simply arbitrary numbers assigned by the SAE that have no real correlation with each other (Fig. 8). Viscosity is measured in centistokes (cSt) at 100º C.

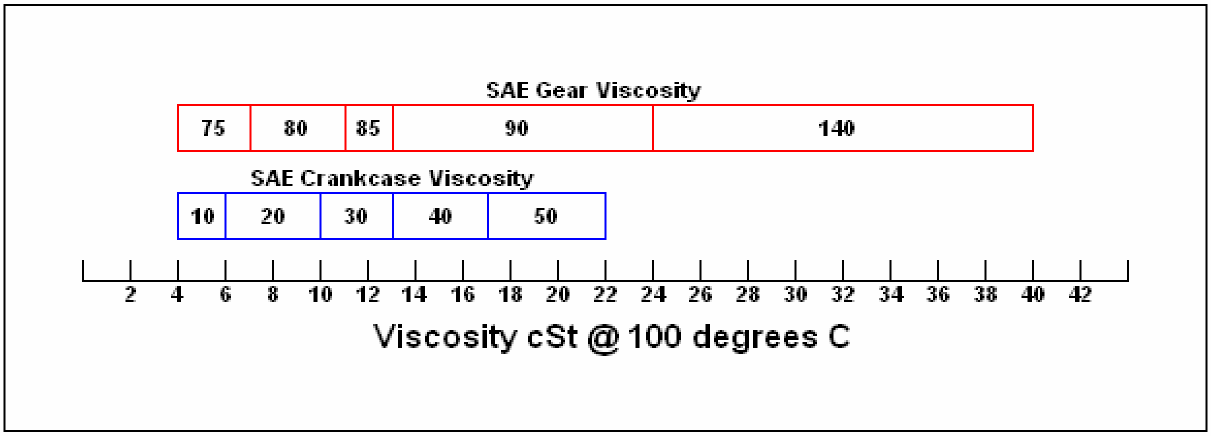


Figure 8. A comparison of motor and gear oil viscosities.

(1) Note. From *Hackett, More than you ever wanted to know about motor oil*. n.d.

At the end of it all, we are still left with a question: "Are gear and engine oils interchangeable?" We already know they are not the same, we now know why. Because of these differences, it's possible to use regular engine oil in a transmission but never permissible to use gear oil in an engine.

In our motorcycles, we often are forced to worry about whether a particular oil is safe for our wet clutch. Several tests have been done to determine which additives provide the best protection and retain the highest degree of friction for the clutch plates. In 1994, Scott and Suntiwattana tested several different additive packages against each other and against base mineral oil in several different clutch configurations. He determined that all additives in common use in gear oils such as those for extreme pressure/anti-wear (sulphur-phosphorus), corrosion inhibitor/metal deactivator (for copper alloys), viscosity index improver (polyisobutene), pour point depressant (polymethacrylate) and corrosion inhibitor (for ferrous metals), had beneficial effects on the friction ratings of the clutches. In particular, he found that the sulphur-phosphorus additives (extreme pressure/anti-wear) provided significant reductions in lockup time and increased friction, with or without other additives. This may mean that true gear oil or those made especially for our primaries may actually be better performers.

Since starting this paper Harley-Davidson® has changed their lineup somewhat. Instead of the expected removal of mineral-based oils from their recommendations, they seem to have improved, or at least changed the line. Sport-Trans is no longer offered or recommended, the preferred transmission and primary fluid for all H-D motorcycles (with the exception of the VRSC) is now FORMULA+ Transmission and Primary Chaincase Lubricant. This has not been tested for this report but may be tested at some point in the future. Through laboratory testing we have determined that Sport-Trans tests as a 40 weight oil (Fig. 4), with relatively high levels of phosphorous (assumed to be part of the extreme pressure additives indicated above), magnesium, and zinc. The sample tested contained no molybdenum.

Oil Change Frequency

Next to “should I use synthetic?” and “what brand of oil should I use?”, how often to change one’s oil is the most popular question asked. Auto makers, like GM, have begun to install computers to tell the drivers when to change the oil. In my personal vehicle this has never come on in under 5000 miles of driving.

Engine wear actually decreases as oil ages. This has been substantiated in testing conducted by Ford Motor Co. and ConocoPhillips. What this means is that changing oil frequently actually causes more engine wear than using more of the lifespan of the oil (Gao, et al, 2003). This flies in the face of “conventional wisdom” and certainly what our dads taught us.

Changing oil makes people feel good, they see that clear, cool oil going into the tank and they would never believe that they are doing any harm to their engine. You can actually baby a vehicle to death. I’ve seen it happen: While in the Army we had several completely useless trucks with under 5000 miles. They were maintained daily and they showed the wear.

So when do you change the oil? Several factors go into it. First, if you are a low mileage rider, you should be changing the oil once a year, before it goes into storage for the winter. Leaving nasties sitting in your engine over the winter months is far worse than “over-changing” the oil. Next, we have to look at why we would want to change oil.

The qualities in oil that change over time are its viscosity, the TBN, and suspended solids. A good oil test can be invaluable in determining what’s going on in your engine and with your oil. It will show these attributes over time if you test regularly and also warn you ahead of time if serious issues loom. High suspended solids would mean it’s time to change the filter, increasing viscosity might mean that the oil is getting heat damaged and lowering TBN can mean the oil is getting close to absorbing all the acids it can. The true time to change the oil is when the oil says to change it. Simply looking dark (this happens after about 500 miles) is not a good reason. Despite the benefits that extend far beyond using the oil till its done, people typically do not employ oil analysis as part of their preventive maintenance. It can be an invaluable tool and I recommend it highly.

One thing that you can do to help both your oil and your engine last is to use an air filter, one that actually filters the air, not just looks good. When dust is allowed to enter the intake tract, it abrades everything it touches, most notably valve stems and guides. When it enters the cylinders it sticks to the walls of the cylinders where it is washed into the crankcase in and by the oil. These microscopic particles do serious harm to your engine’s man precisely machined parts.

Oil can circulate several times before it ever passes through the filter because of pressure bypass valves, so simply having an oil filter is not necessarily a suitable defense, Leave the velocity stacks and open scoops to the drag racers that tear their engines down often; use a good filter.

Without oil analysis, without sophisticated computers, we can only approximate when to change oil in our motorcycles. The manufacturer's recommendation of 5000 miles seems a sound one given the information available. For extreme conditions, adjust downwards slightly but a minimum interval should be kept at 3000 miles. In the case of a catastrophic event such as the carburetor flooding the crankcase, severe overheating resulting in the burning of the oil, or failure of a mechanical part within the engine, of course; change the oil immediately.

What is "Harley-Davidson®" Oil?

It may be easier to state what Harley-Davidson® oil is not. One of the premises of this entire study was that H-D oil was "the same as Citgo®." If there's one thing we were able to figure out is that despite the oil reportedly being bottled by Citgo, H-D oil is not the same as Citgo oil. H-D uses magnesium as part of its acid neutralizing package where Citgo uses none, however; interestingly, anti-wear additives were similar with near identical levels of zinc and phosphorous. Citgo also uses molybdenum where H-D oils have none. The most marked difference came in the TBN rating of the virgin oil samples. H-D oils ranged in the high 11's (some of the highest tested) where Citgo oils were in the 8's (Fig. 9).

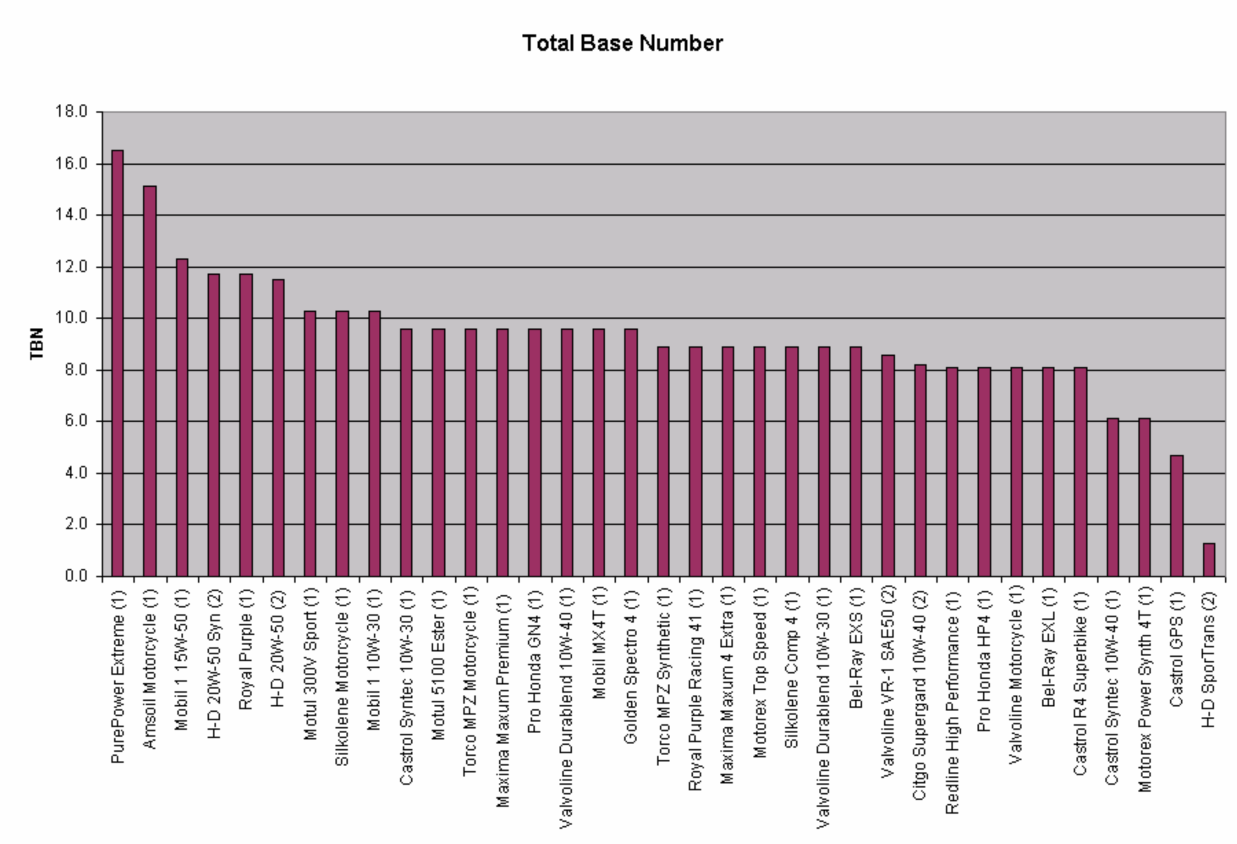


Figure 9. A comparison of TBN ratings of motor oils.

(1) Note. From *Motorcycle Consumer News, Oil Investigation Update*. 2003

(2) Note. From *Alven, solicited testing*. 2004

So, what is Harley-Davidson® oil? It seems H-D oil is a pretty well formulated oil for your engine. It does test on the upper end of the viscosity scale for it's rating with the SYN3 slightly thicker than the mineral-based H-D oils; it was actually the highest viscosity tested. The TBN is among the highest tested and it contains no molybdenum. All in all it's everything we all say we want in an oil. The heat stability tests we ran, despite some inconsistencies in some samples, seem to indicate a fair level of resistance to heat aging (Fig. 7).

Conclusion

We had hoped to change the world with our results. Use oil, use the proper grade, and change it when you are supposed to. After all this work; that's the best advice I've learned I can give. Conspiracies were to be revealed and the world would have been a better place with these tests. What was learned is that there are no simple answers. For those that care to dig, the information is available. For those that do not care to worry themselves, it's reasonable to follow the manufacturer's recommendations and simply enjoy the ride.

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