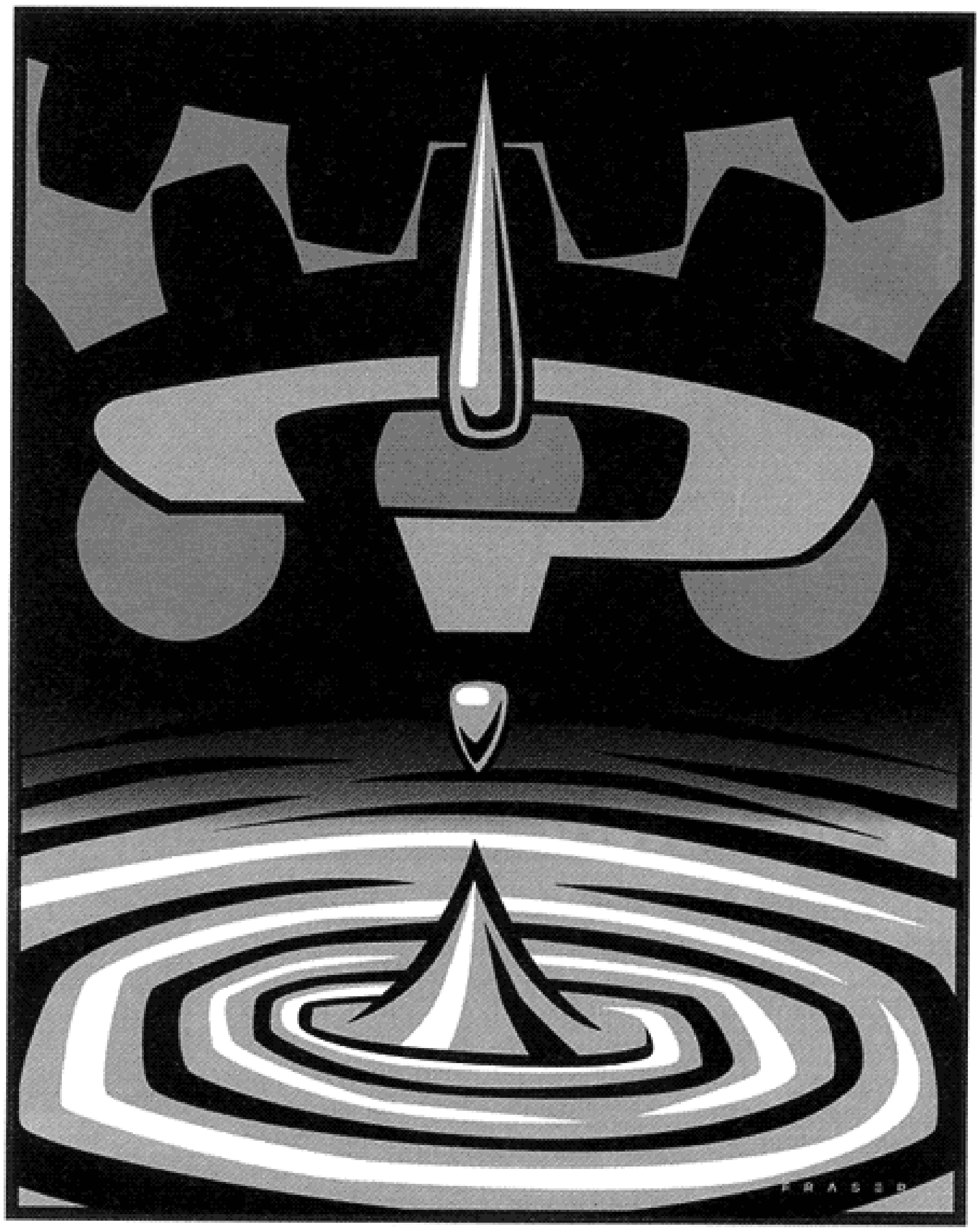
Motor Oil

The myths, facts and mysteries of the slippery stuff that keeps your engine happy



Here's the bottom line on motor oils: You really can't go wrong by following the recommendations given in your owner's manual. Your motorcycle's maker has dyno-tested its engine with a crankcase full of the specified oil, or one with the same American Petroleum Institute (API) rating. You can be sure that particular oil will do the job. Will it do the job better than any other oil? Will it still do the job if the engine is no longer as its manufacturer made it? Not necessarily, as you will learn by reading further.

The API's ratings once went from "SA" (guaranteed to be oil) through the alphabet to "SE," and was extended to "SE/CC" (you can't drive a nail through a film of this stuff). Today the API has fewer performance grades, only "SH" and "SG" for spark-ignition engines, with an "SH/CD" rating for oils good enough to be used in passenger-car diesels. The motor oils bearing these API markings have been test-certified for today's engines, which are in turn constructed with these oils in mind.

You should be aware that motor oils are now being compounded not just for lubrication, but to improve fuel economy as well. Oils have always been compounded with a thought for fluid drag; this is the first time it has been made a priority. The API has two fuel economy ratings: "Energy Conserving," for motor oils that yield a 1.5 percent reduction in fuel consumption as compared with a reference oil; "Energy Conserving II" is an oil that provides a 2.7 percent drop in fuel consumption.

By Gordon Jennings Illustration by Douglas Fraser

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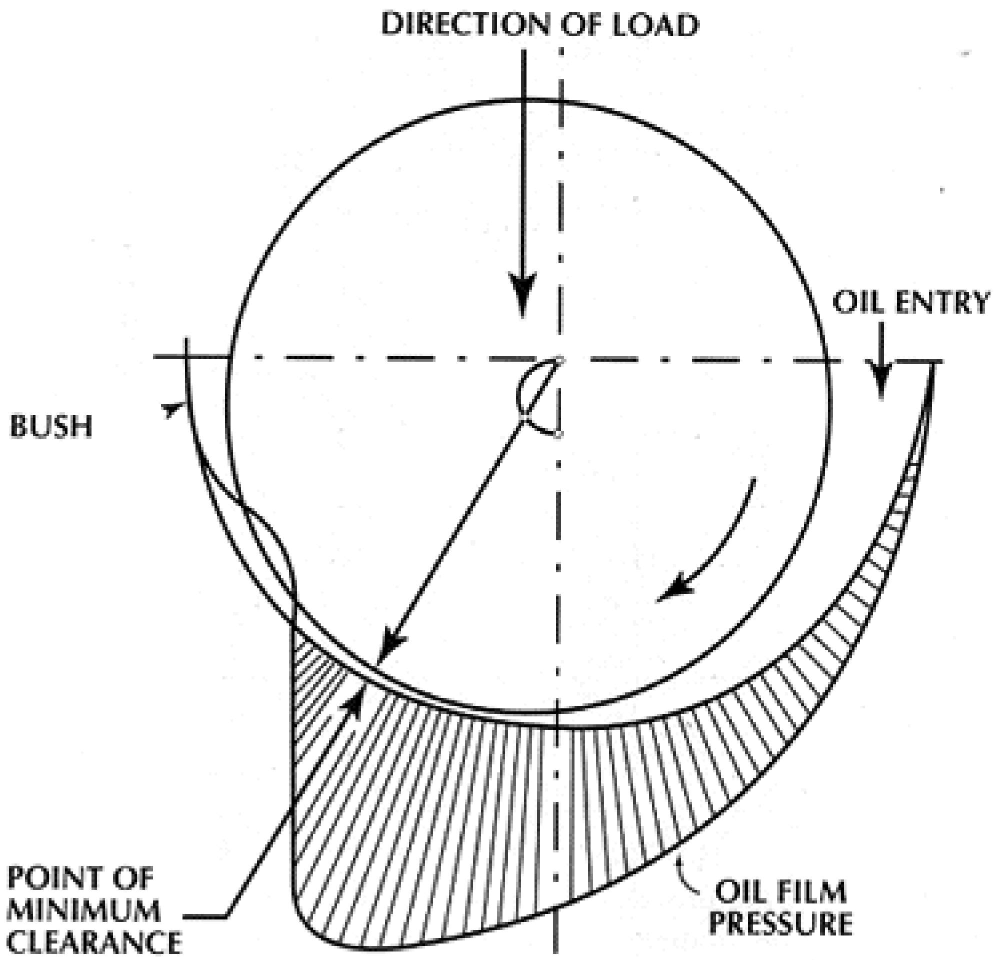

■ **This diagram illustrates the protective "hydrodynamic wedge" of oil that forms between a spinning shaft and an adjacent bushing. Note that as the shaft spins (clockwise in this diagram), oil is "pulled" into the gap (on the right) due to the lubricant's viscosity. Note also that the oil film pressure becomes highest at the point of minimum clearance (and maximum load), thus preventing metal-to-metal contact.**

As you might expect, energy conserving oils' drag reduction benefits also show up as increased horsepower. Both thermal and mechanical losses diminish the power liberated in the combustion process on its way to the output shaft. The work of pumping air in and out of the engine accounts for the majority of the mechanical losses. The rest is mostly lost to fluid drag on the piston, which is, all other things being equal, largely a function of oil viscosity.

Friction exists even in the absence of actual contact between opposed surfaces. The cylinder wall's oil film normally prevents it from being touched by the piston, but it is itself a source of friction, if we take that to mean resistance to relative motion. Millions of molecules on each side of the gap try to stick together but get pulled apart. The sum of millions of molecules' minute resistance to separation comprises viscous drag, the source of most friction in a running engine.

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Viscosity aside, the most important property of an oil is that it be "oily." Introducing any liquid between a piston and cylinder wall, for example, will reduce friction between the two surfaces. The degree to which friction will be reduced is, broadly speaking, a function of the liquid's viscosity. But maple syrup and motor oil of essentially identical viscosity do not lubricate equally, as you can discover by rubbing samples of each between thumb and forefinger.

If "oiliness" were the only quality to be considered in choosing motor oils, we'd be squeezing all of ours from castor beans. Castor oil, the smell of which once perfumed the air at motor races, is the oiliest of oils and it remains in some respects the supreme lubricant. It does oxidize too readily, however, forming ring-sticking gums and varnishes, and daubing fouling deposits on spark plugs. In a running engine, castor oil goes right to work gluing piston rings in their grooves and slathering gum and varnish everywhere. You wouldn't want it in any engine that can survive without its help.

But castor oil, a mixture of ricinoleic and triricinoleic glycerides, plus 10 to 12 percent of other fatty acids, remains one of the best lubricants for two-stroke racing engines. Castor oil clings to metal with such tenacity it cannot be removed except by machining. It is an exceptionally effective film lubricant.

Oil forming a hydrodynamic wedge between surfaces keeps pistons and bushing-type bearings from metal-to-metal contact. Viscosity pulls oil between a moving piston and the adjacent cylinder wall, or a shaft and bearing, and pressurizes the gap. This pressure increases with viscosity and speed, and in a well-designed engine almost totally prevents scrubbing contact.

The qualifying "almost" is needed because hydrodynamic action is not present in an engine at start-up, and it collapses around the pistons and rings at the ends of their strokes. Under these conditions parts are protected only by film lubrication, which is provided by the dipolarity of oil molecules. The molecules behave like tiny magnets and adhere to ferrous metals and each other.

One of the great improvements in motor oils came circa 1950, when the detergent/dispersant additives developed for diesels came into more general use. Alas, these brought with them unfortunate consequences for old, high-mileage engines. In those, the detergents sometimes dislodged great clots of oxidized oil filth to clog filters and oil passages. Engine failures caused by detritus liberated in this manner put additive oils in bad repute, with the result that a few people still buy and use straight non-additive oils.

The first oil additive was probably the spoon of sulfur old-time truck operators tossed into axle and transmission housings. The sulfur reacted with gear-tooth steel to give the gears an iron sulfide surface film. The film was important because the relative speeds between meshing gears is too low to form

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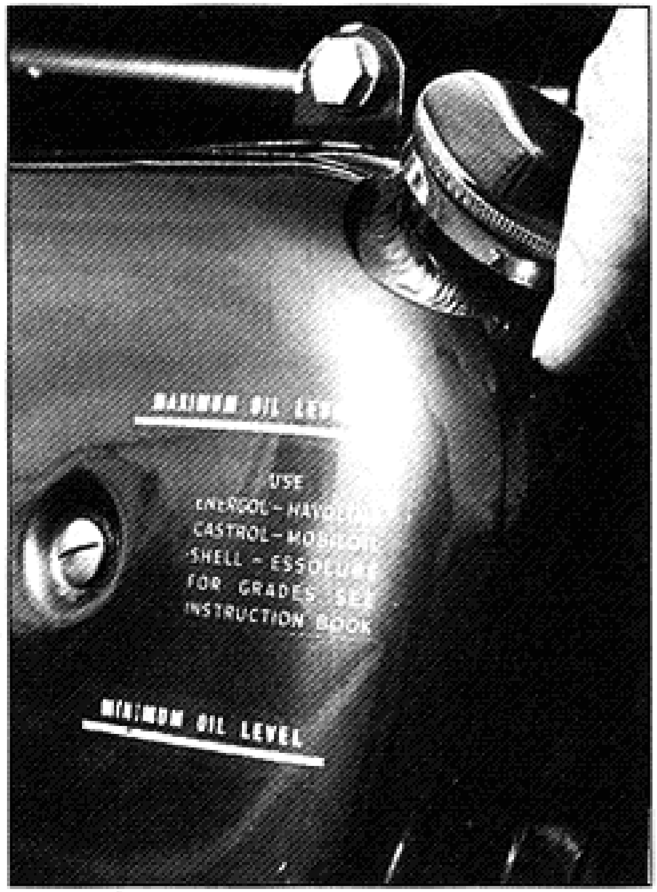
a fluid wedge strong enough to resist the extremely high gear-tooth loads.

Engines also have points at which loadings can exceed the carrying capacity of the fluid wedge. Take the tiny contact area between the exhaust cam and follower, for example. The load there rises to roughly 1500 pounds for each ounce of valvetrain weight at high engine speeds. Full throttle adds 80 pounds of load for each square inch of valve head area, meaning the load focused on the cam/follower contact patch can reach pressures in the order of 20,000 pounds per square inch.

Cams would have to spin faster than they do (half crank speed) to work up a fluid wedge capable of carrying such high loadings. So the job has to be done with film lubrication, which means a more viscous oil, one with special properties (castor), or an Extreme Pressure (EP) additive. It's obvious that film lubrication is important; where some of us go wrong is in leaping to the conclusion that those who compound motor oils have overlooked this very point.



■ Motorcycle manufacturers do an extensive amount of testing with various lubricants; don't try and out-think the engineers by using an oil with an API rating not specified in the owner's manual.

Dealers' accessories shelves usually have a selection of flasks filled with liquids I call "mouse milk." This stuff reduces the friction in your wallet enough to make money slip out of it, but may not do anything else. About the best you can hope for from mouse milk is that it will either be more of the same additives already in good-quality motor oils, or at least not get in the way of the additives that do something useful.

Film-condition additives usually are chemically and/or thermally reactive. The sulfur- and phosphorous-based compounds react with iron to form slippery iron sulfides, as previously noted, or wear-resistant iron phosphides. Fatty acids, like those in castor oil, react with iron to make low-friction iron soaps.

Thermally reactive "liquid metals," like molybdenum dithiophospate, are oil-soluble chemical compounds; molybdenum sulfide, on the other hand, is a cheap dry-slide lubricant sometimes used in greases. If you put

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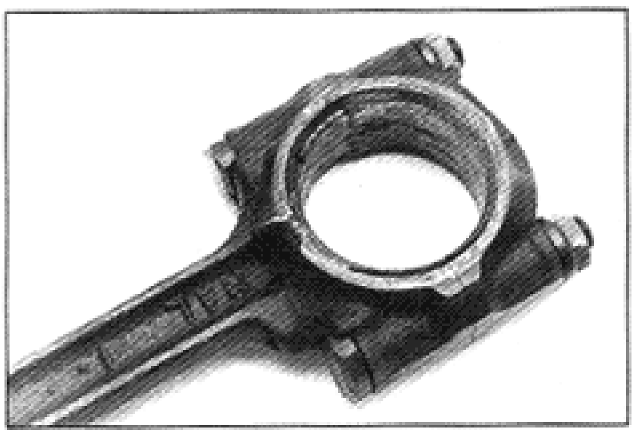

■ **Should one component of your engine's lubricative system fail, damage like this destroyed rod bearing will result. This failure was fortunately caught early, before imminent catastrophe occurred.**

MOS or other dry-slide lubricant powders like colloidal graphite in motor oil, these solids may settle or filter out. Worse, they may become a barrier blocking the more effective reactive additives.

The liquid metals dissolve in oil, like salt in water, and remain in solution at all normal engine operating temperatures. But when friction heats the liquid metal compounds they come apart and their metallic component is plated on the hot spot. This stops the most potent, least obvious wear process in today's filter-protected engines: direct, scrubbing contact between a cam and follower, gear teeth, etc. This contact results in wear largely due to friction welding: Friction melts pinpoint areas of metal on both sides of the contact area, and they weld themselves together. These minute welded particles then break away, and after enough of them are carried off by the oil, the part needs replacement.

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The role of liquid metals—usually molybdenum, tungsten or zinc compounds—is both to interfere with friction welding, and to sacrifice itself to the wear that otherwise would devour engine parts. Unfortunately, phosphorous compounds degrade catalytic converter performance, so the feds limit the amount of additives like zinc dialkyldithiophosphate in motor oils. But in nearly all instances there is enough to last from one oil change to the next.

In the years before we had effective micron-level air and oil filtering, abrasive engine wear was a problem. The typical spark-ignition engine sucks in 10,000 gallons of air for every gallon of fuel it consumes. If you don't filter that air, it carries grit into your bike's engine posthaste. The larger particles do little damage unless they get caught between a

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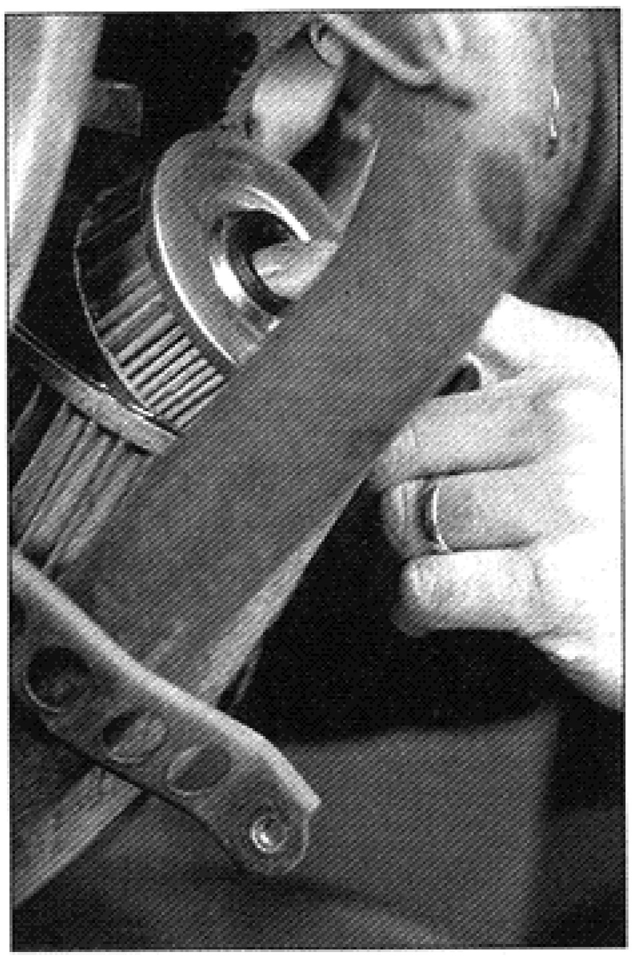
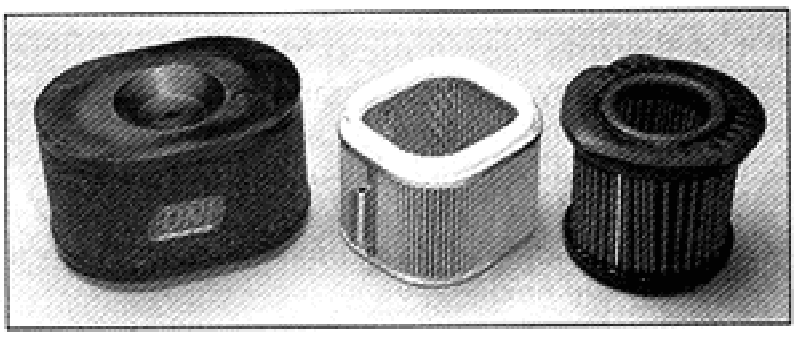
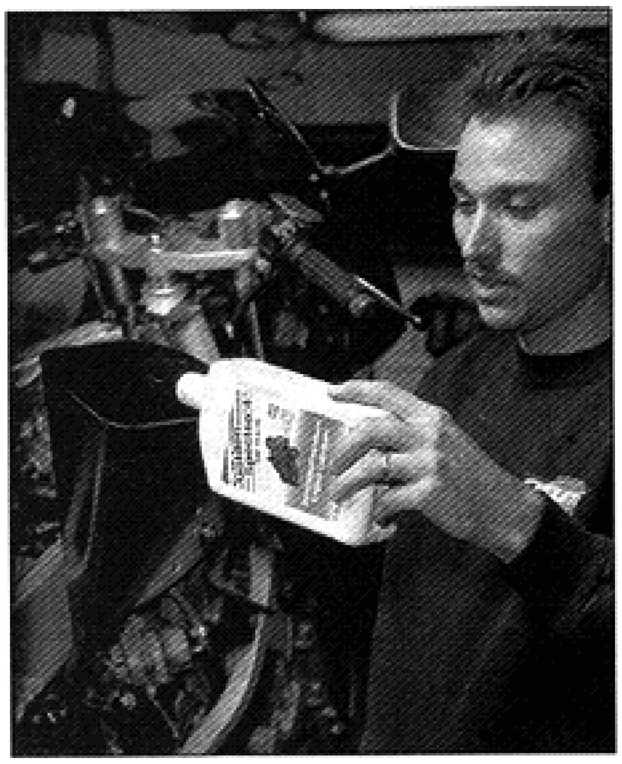


■ Obviously, a functioning oil filter is crucial to your engine's health. Replacing it at specified intervals ensures the oil won't cause more damage than it prevents.



■ Today's air filters are a far cry from the old "gravel strainer" carb screens of old. A modern air filter allows the oil film separating the engine's moving parts to submerge and render harmless any grit particles small enough to get past it.



■ As long as you follow the manufacturer's specific oil rating recommendations, you can't go wrong by using well-known brand name products.

valve and its seat, pitting both severely.

Virtually all dust particles are silica or silicon oxide, an extraordinarily hard substance with plenty of sharp edges. Engines with inadequate (or non-existent) air filters eat a huge amount of this grit. The good news is, most of it leaves with the exhaust gases. The bad news? What does stay can do severe damage, whether it's in the wrong place or is carried around in the wrong oil.

Modern air and oil filters trap just about everything larger than a micron (one millionth of a meter, or 0.000039-inch) in diameter. Particles of that size are enveloped by the oil film separating an engine's moving parts. Even a very light oil provides this protection. SAE 5 seems watery, but it has a film depth of not less than 0.001-inch, deep enough to submerge and render harmless grit particles smaller than 26 microns.

Abrasive wear was a bigger problem back when the typical motorcycle air filter was a coarse screen capable of stopping nothing much smaller than pea gravel. The old gravel strainers gave free passage to the 20-micron grit that does the worst damage, especially to piston rings.

Fine grit was/is also a great killer of roller cranks. Grit becomes imbedded in bearing cages and makes them depressingly effective crankpin grinders. You can prevent this kind of damage by using the thick oils, SAE 30 and above, envisioned and recommended by the people who built those old engines.

Thick, high-viscosity oils are good for enveloping grit. They also do a great job of sealing and cushioning, which are two of the important functions of all motor oils (much more 30 years ago than today). The aluminum piston alloys in use circa 1960 had high expansion rates and poor high-temperature strength. Accordingly, they needed to be surrounded by thick oil, to seal the fire trying to blow past the generous clearances—and to keep them from rattling in their bores.

Thick oils spread the concentrated loads between roller bearings and their races. The mechanism of rolling-element bearing failure usually is "brinelling," fatigue-related flaking, of the inner bearing race. Under load, the race under the roller (or ball) yields minutely as the bearing turns, just as a paved street yields to the weight of a passing truck. And in time, the bearing race, just like the street, begins to break up.

Plain insert-type bearings can also fall victim to fatigue failure. You can bring about their early demise by feeding them a too-thick oil, which will turn into a too-thin oil in the bearing. The oil in plain bearings, whether connecting rod inserts or the floating bushings in a turbocharger, is heated by fluid shearing. If the oil's viscosity and bearing clearance are properly matched, there will be sufficient oil flowing past the bearing to keep it cool.

When you put SAE 40 oil in an engine designed for SAE 10-30, you may intend to protect its bearings with the thicker oil. But the increased oil viscosity, and resulting reduction of flow, can overheat the bearing. The metals used in plain bearings—copper, lead and aluminum—typically lose half their ambient temperature strength at 200° F. Copper-lead bearings are stressed near their elastic limit at redline crank speeds, even with crankcase oil temperatures below 250° F. Pour in some thick oil, or a "mouse-milk" viscosity-index improver, and you'll reduce the bearing's oil flow, which will make it hotter and may cause it to fail.

Engine oils are viscosity-rated by subjecting them to the arcane arts of viscometry at 40° F, then heating them and repeating the test at 210° F. When you see a 10W30 rating on an oil, the "W" means the oil's base stock has ac-

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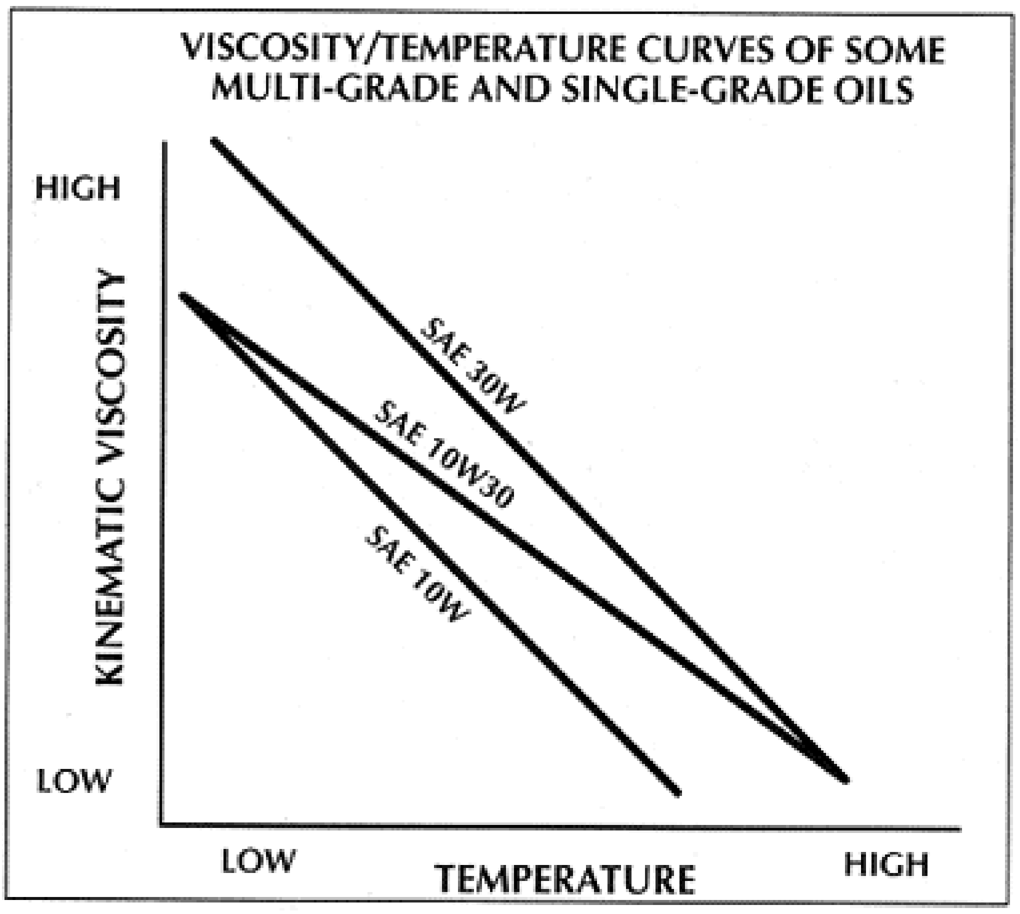
tually been tested down to 0° F with a cold cranking simulator. It is assumed, for purposes of viscosity classification, that motor oils are "Newtonian" in their loss of viscosity with temperature (meaning that their rate of loss is fairly constant). The rate of loss is given as a "viscosity index" number, and in this respect some oils are better than others.



■ **This graph showing viscosity/temperature curves demonstrates a multi-grade (10W30) oil's ability to have the viscosity of straight 10W oil at low temperatures, yet gradually take on the properties of straight 30W oil as temperatures rise.**

Multi-grade oils are made so by chemical additives called "viscosity index improvers." These additives contain either colloidally dispersed long-chain molecules that dissolve into true solution as temperature rises, or spiral molecules that open up and get longer with increases in temperature. Both of these actions "thicken" heat-thinned oil. Add the right VI improver and you get, for example, an oil that tests SAE 10 at 40° F but looks more like SAE 30 oil at 210° F. A multi-grade oil doesn't thicken with increased temperature, it just doesn't thin as much as a single-grade oil.

One thing you should know about multi-grade oils is that their VI-improving additives will wear out. You can fool Mother Nature, but not forever: Long-chain molecules shear apart, so the 10-30 oil you pour into your motorcycle's engine becomes 10-25 oil after a time, and then 10-20, 10-15, right down to 10-10 if you cover enough miles between oil changes.

Refined petroleum base stocks can contain dissolved waxes that solidify at very low temperatures. Today's motor oil base stocks are refined mostly from asphaltic/aromatic crude oils, which do not ordinarily present the serious wax problem encountered with paraffinic crudes, but will turn to a petroleum jelly in the small hours of Midwestern winter nights. There's an additive for this, too, a "pour-point suppressant." Other additives prevent oil oxidation, frothing, and neutralize acids created by combustion.

■ **Besides the obvious SAE viscosity rating, you should also look for the API performance rating ("SH/CD" on this label) when shopping for oil. The "Energy Conserving" tag is one of the API's new fuel consumption standards for motor oils.**

Over the last couple of decades we have seen the rise of "synthetic" and "synthetic blend" base stocks in motor oils. The big difference between plain old refined oil and synthetic oil is that the latter is, well, synthesized. When crude is refined, it is effectively sifted. The SAE 30 base stock you get in the sifting operation represents an average of molecule sizes, some being larger and others smaller. Shearing in a running engine breaks the big molecules apart faster than the little ones, which reduces the average size of molecules in the oil and thins it.

In contrast, synthetic base stocks' molecules are uniform in size, having been assembled out of fragments in a molecular stew. Synthetic oils also contain none of the waxes that can block low-temperature flow, and none of the instant-sludge crude-oil cruds or aromatics that vaporize and drift away the first time a spark plug fires anywhere near them.

I was not impressed by some of the early synthetic motor oils, which were compounded using cheap glycols as a base. Union Carbide's polyalkylenes weren't too bad as lubricants, and could be fortified with additives. But the polyalkylenes oozed past gaskets and seals; some others synthesized from gases returned to gaseous form in the hot engine environment.

The better synthetic base stocks in use today are record-holders on the viscosity index scale. They still need a good squirt of VI booster to qualify as multi-grade oils, but they need less of it than refined base stocks. This is important, as polymeric viscosity index improvers' long molecules are unstable in shear. The less help your SAE 10W30 motor oil needs to meet its high temperature obligations, the longer it will be effective.

Good synthetic motor oils also have better non-Newtonian, "apparent viscosity" behaviors. Oil displaying these "kinematically diminished" properties behaves like a thinner oil when rubbing speeds are high enough to build a thick fluid wedge.

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Which synthetic oils are best in terms of apparent viscosity? I don't know, and neither does anyone else who lacks a laboratory full of expensive, complicated equipment. I also don't know which additives, or how much of each, is present in the containers of motor oil—refined or synthetic—you'll see displayed at dealerships, service stations and the like. That information is a closely held trade secret.

So, after all this talk of motor oils, how do you tell good from bad? The bottom

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line here is, you buy the label on the container; you buy reputation. When you see a plastic bottle labeled "Zowie Lube," with small print that says it was packaged by "O'Grady's Motor & Hemorrhoid Products," put it back on the shelf and reach for something familiar. When I tell you to rely on brand-name products, I'm not just sucking up to this magazine's advertisers.

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Castrol is not an advertiser, but I will tell you the company has been making motor oils since we've had motors and I don't think it would knowingly sell you anything that would tarnish its good name. I've used Castrol's motor oils for both racing and street applications, without disappointments. Refined-base GTX, sold super-cheap at supermarkets everywhere, is a very good motor oil, and might be better than some of the high-priced synthetics.

Mobil, which is an advertiser, long ago began developing synthetic motor oils and put its considerable technical resources to work creating a good one. They came up with Mobil 1, an oil using a mostly polyalphaolefin base stock reinforced with a big percentage of polyol ester—the latter being an especially good lubricant in its own right. Mobil 1 probably is today's best widely available motor oil. As a result of the preparatory research I have done prior to writing this article, I bought (yes, bought!) Mobil 1 for use in my own vehicles.

Red Line, an advertiser, is making a name for itself as a source of all-synthetic motor oils, and this company, like Mobil, relies on big percentages of polyol esters in its base stocks. My contacts in two- and four-wheeled racing tell me Red Line's oils are producing excellent results in everything from NASCAR's stockers to motorcycle GP racing's shrieking two-stroke engines.

Keep in mind that your motorcycle was extensively tested with its cavities full of the lubricants specified by its maker. Motorcycle manufacturers don't test their models on oil specially compounded to keep motorcycle engines, clutches and transmissions happy. They instead do the sensible thing and design hardware compatible with the oils they know you'll be able to find. It's the smart thing to do, and it works right up to the point where you ignore their advice. MC