# stef•tech

*Par Stéphane Miville*

**Oils are confusing. While snowmobile manufacturers' oil requirements appear general, able to be satisfied by a variety of oils that may be mineral, vegetable (at least in part), or synthetic, you will also meet persons who swear absolutely by particular oils – often very expensive ones. Synthetic oils, for example, come in many forms with mouth-filling names like poly alpha olefin and neopentyl polyol ester. What, if anything, do these names mean in terms of snowmobile engine performance and useful life? Are there magic elixirs which can double the life of your machine? Or can we safely echo the claims of old-timers that "Oil is oil, so just buy the cheapest you can find"?**

# oils

by Kevin Cameron

If money makes no difference, we can happily pay $14 a litre for a premium oil. If it does make a difference, we'd like to know enough to spend our money sensibly.

There are some things that can be learned about oils, but the ultimate truth is that manufacturers' oil testing provides most of our useful information, through the requirements printed in our snowmobile owners' manuals. More can come from our own and from friends' experience. The rest is general information – about how oils are made and from what, what oil additives do, and what problems oil actually addresses. This kind of general information can prepare us to read oil makers' claims objectively.

The obvious thing that oils do is to lubricate. As a piston ring slides on an oily cylinder wall, the viscosity, or internal friction of the oil prevents it from just being scraped off to leave ring and cylinder in metal-to-metal contact. Instead, some of the oil is dragged between the moving parts to form a pressure-generating wedge that separates them. The formation of this wedge depends upon (a) the viscosity of the oil and (b) the relative speed of the parts. The more viscous the oil, and the higher the relative speed, the thicker the oil wedge that forms, and the farther separated the parts are – and vice-versa. Force is required to slide the piston ring over the oil film, so there is a relationship between oil viscosity and engine friction. In practice, the viscosity choice is a compromise – high enough to give effective separation of moving parts, but not high enough to result in excessive friction loss.

We can see changes in this compromise in four-stroke auto and motorcycle oils, whose viscosity has declined in the past two decades. This change has been made to improve fuel economy (cutting viscosity-related friction loss), but has only been made possible by improved surface finishes on cylinder walls and crank journals. Smoother parts can be lubricated adequately by thinner oil films.

Oils must also lubricate parts when full fluid oil films are not present. This occurs at start-up, when most of the oil has drained off the parts. It also occurs wherever the relative motion of parts is very slow – as between piston rings and cylinder wall at top and bottom center positions (TDC and BDC). Because the piston rings are moving very slowly or are stopped at these positions, oil has time to squeeze out, leaving ring and cylinder wall in much closer contact. It is for this reason that most cylinder wear occurs where the rings are stopped at TDC (high gas pressure presses them hard against the cylinder) and less at BDC (essentially no gas pressure behind the rings).

This situation is called "mixed lubrication" because part of the load is carried by oil viscosity, 'trying' to build up to a full fluid film, and part of it is carried by surface-to-surface contact. I did not say 'metal-to-metal' contact because additives in the oil act to prevent this.

One leading class of additive is oil molecules that have the ability to attach themselves strongly to metal surfaces. They are said to posses 'oiliness' and are called friction modifiers. All oil molecules are long flexible chains, typically with a backbone of carbon atoms, each of which carries one or more hydrogen atoms bonded to it. Those with the property of 'oiliness' terminate at one end in a polar group, a cluster of atoms that can electrically bond to metal surfaces. Metal surfaces become coated with at least a single layer and perhaps more, of these grass-like strands.

Friction with full-film lubrication is of the order of .001-.002 times the applied load, and dry metal-to-metal friction is thousands of times greater. In metal-to-metal friction, great heat is generated, which serves to boil away any remaining lubricant. Local welding and surface plucking follow. But when an additive layer is present and full-film lubrication breaks down, friction remains low (about .01) so only limited frictional heat is generated and parts surfaces are protected. If the additive layer is scraped off, it "heals" itself from


additive present in the surrounding oil. This action is the basis of the excellent anti-seize behavior of the old castor-based racing oils.

More potent are the anti-wear additives, such as the oft-mentioned 'zinc', or zinc dialkyl dithiophosphate. At points of high friction, the local temperature breaks down these compounds, releasing active phosphorus, sulfur, or chlorine. These react with the metal surface to form strong but low-friction sacrificial layers of metal phosphides or chlorides. When strong local contact is made between moving parts, these layers offer physical protection and limit heat generation by their low friction. Under greater pressure, the surface layers may be damaged or even scraped off, sacrificing themselves to protect the metal beneath from damage. The surface layer then reforms from additive remaining in the oil.

The lubrication of rolling-element bearings is a special case. Such bearings require very little oil, but some is essential to their survival. Through a strange property called "elasto-hydrodynamic behavior", even a very thin film of oil on roller or ball races serves to spread out the load, extending the fatigue life of the parts. Under extreme pressure, oil viscosity can (momentarily) increase by a factor of 30,000, making oil act like a solid lubricant. In addition, the presence of oil enlarges the heat path out of hot-running con-rod rollers and into the cooler rod or crankpin.

Another important additive class is the dispersants. As an engine runs, oil in contact with the hot top piston ring and its groove can polymerize (oil chains link together, increasing their viscosity) to form a gum that can eventually stick the piston ring in its groove. Dispersants form surface layers on parts and on particles of polymerized oil, preventing the one from building up on the other. As an example, I used castor-based oil in two-stroke motorcycle engines run at the Daytona 200 mile race, but noticed that piston rings were often at least partly stuck after two hours of high-speed operation. Switching to another oil with a high loading of dispersant kept the rings free.

You will hear reference made to ashless dispersants. Earlier oils contained detergents (for the purpose of keeping rings free) whose combustion yielded solid products that could, over time, block or seize the exhaust gates or powervalves used on some sled engines. Modern ashless dispersants leave no such solid ash.

Of special importance to vehicles that spend long periods of time out of service are anti-corrosion additives, intended to prevent rust, or conversion of aluminum and magnesium into nasty white powder. Older snowmobilers will remember that some early synthetic oils (late 1960s-'70s) actually promoted rusting. These oils not only lacked anti-corrosion additives, but actively absorbed moisture from the air.

A related function is performed by tackifiers, whose job is to hold oil on parts rather than allow it to drain away during periods of non-operation.

Anti-oxidants operate to slow the formation of polymer gums and varnish from hot oil exposed to air.

Important at low temperatures are the pour-point depressants, which keep oils from waxing into unpumpable solids or slushes. Wax forming components in oils can be refined out, but some are valuable lubricants. Therefore PPDs are used to surround and isolate wax particles when they are small, preventing them from clumping together.

Additive chemistry is complicated by the problem of keeping the necessary quantity of the additive dissolved or suspended in the oil. Synthetic oils present special problems in additive package development.

An often-discussed oil additive is polyisobutylene (PIB), which is a multi-purpose additive. It is actually uncured synthetic rubber, and its very long molecules help to resist temperature viscosity loss. It also acts against seizure. A major application of PIB is as an anti-smoke additive. PIB's long molecules resist oil's break-up into the tiny particles that are seen as exhaust smoke. As you would expect, use of a large amount of such a viscous additive increases cold-starting torque. Fortunately it is an effective anti-smoke additive when used in very small amounts.

Don't switch to a new brand or type of oil without good reason. The nature of lubrication and of the additive technologies that the industry employs make it unlikely that a given product will give results dramatically different from another under normal use. For those contemplating changing oils, good reasons would be running problems such as piston ring or exhaust gate sticking, off-season internal rusting, and the like. If there is excessive smoke, the oil pump setting should be checked first. If you run low on your own brand of oil in the field, by all means use whatever you can find that meets your engine maker's oil requirement until you can return to your usual. Be aware that in engines using pre-mixed oil and fuel, any change in oil mixing ratio also changes the fuel mixture. The more oil you add, the leaner your engine runs.

## SNAKE OIL?

Many of us have seen demonstrations in which a salesman puts a few drops of your favorite oil into his rotating-ball lube tester. In a few seconds the oil is smoking – failure! But help is at hand, as the salesman adds one drop of his elixir. The smoke stops! I'll take twenty cases right now! But no – the elixir is a chlorine-based extreme pressure additive that actually causes rapid polishing wear in engines, and in some cases promotes detonation as well (even chlorine laundry bleach stops the smoke). Verdict; engines are not rotating ball lube testers, and they aren't compatible with all types of additives! Other mystery lubes contain vanishingly small particles of Teflon. It says here on the label, "Approved for Aviation Use". That's gotta mean something, eh? Actually, such 'approval' means only that the additive has not been found to cause harm. Or how about demos in which an engine is "treated" with mystery elixir, has all its oil drained out, and is then started and driven away? No one in the lube business recommends you try it, but they admit that the additives in any good modern engine oil will permit this trick to work.

## MINERAL, VEGETABLE, OR SYNTHETIC?

Lubrication and other studies performed with pure substances have revealed the properties that are desirable in oil molecules. There are three basic ways of obtaining such desired structures. One is to isolate them from petroleum refinery streams. This is done by use of selective solvents. Another is to allow living plants such as castor, rapeseed, or jojoba, to synthesize the desired molecular structures. Plant-derived oiliness additives are valuable components of many high performance oils. The third method is to employ chemical synthesis to deliberately create the desired oil molecules.

Petroleum oil as it comes from a crude oil distillation tower is a mixture of many molecular structures of similar boiling point. There are straight chains, branched chains, and ring structures. We can compare a simple petroleum oil of this kind with an army of conscripts – there are tall soldiers and short ones, fat ones, honest ones – a mixture of all qualities. As the oil is refined, most of the less desirable structures are removed, and what remains is much closer to the ideal. This is analogous to an elite commando unit. Top quality mineral oils are made in this way.

Vegetable oils are like an army of clones – all the molecules are identical. Synthetic oils also have this quality, but in them, the structure results from human design rather than natural accident. Because of these differences, it is often pointed out that synthetic oils can better tolerate prolonged high temperatures or other extreme conditions. On the other hand, if the way you use your engine does not create such extreme conditions, paying extra for such qualities is purely discretionary. The place to look for information is in the manufacturer's oil recommendations. These are the result of systematic testing to destruction of many, many engines, using a variety of lubricants and test procedures. A manufacturer typically spends some hundreds of thousands of dollars annually on such testing.

When the manufacturer of your engine says to use oils that meet a certain testing standard, such as JASO-FC, TC-W-III, or ISO-L-EGD, this means that any oil which has met that standard will give satisfactory service in your engine. Thusfar, no manufacturer's engine creates such severe lubricant conditions that a company has been forced to specify that only a synthetic oil can do the job, but that day may come.

## WHAT ARE SYNTHETICS?

For the most part, synthetic oils were developed at government expense for some kind of specialized military application. Does this make them better oils for snowmobile engines? Not necessarily – the only valid test of oils for snowmobiles is in snowmobile engines. This brings us straight back to the engine manufacturer's oil recommendations and the experience of others using a particular engine type.

An example is the silicone oils – a class of very stable synthetics. The silicones have excellent resistance to oxidation and lose their viscosity with increasing temperature more slowly than other oils. Despite these attractive properties, they are terrible lubricants for any sliding friction application (pistons and rings!) because their chemical inertness makes them unable to bond to surfaces. The lesson in this is that an impressive chemical name and a few outstanding properties do not constitute a lubrication breakthrough. Testing and experience are the name of the lubrication game.

Oil alone cannot do the job in snowmobile engines – it must be aided by a variety of additives matched to both the oil and the application. Therefore the distinct possibility exists that a refined mineral oil bearing an outstanding additive package might do a better job than an excellent synthetic base oil, bearing only a mediocre additive package.

Now what about mystery formulas, supposedly suppressed by evil industry conspiracy, but Available Now at the special price of $19.95 for the four-ounce bottle? Remember that the auto industry pays a fine for every car produced whose fuel consumption exceeds a set level. To avoid this, they search relentlessly for anything that can cut friction loss. Would an inventor, discovering something that really worked, choose to sell his product in ones and twos to individuals? Or would he sell once to the auto industry for untold millions? You know the answer. In the oil business, there are few surprises.

When you see claims of friction reduction, you should know that a typical engine's friction loss is something like 15%. That is, if the gas pressure acting on the pistons produces 100-hp, by the time all friction losses have been subtracted, about 85-hp makes it to the output shaft. It is unlikely that sudden, significant reductions in this friction can be achieved by new lube technology because most of this loss comes from the viscosity that is necessary to achieve effective lubrication in the first place. When you read that a product "Cuts friction loss as much as 3%!" this is not the same as a 3% power gain. What it means is that, under best lab conditions, the product may save 3% of that 15% friction loss, or .15 X .03 = .0045. This is less than half a percent of overall power.

## OIL TEST STANDARDS AND WHAT THEY MEAN

Two-stroke engines today make about ten times more power per square inch of piston crown area than they did fifty years ago. This large increase has demanded constant evolution in lubricant capability to cope with rising temperatures and loads. Each industry sets lubricant standards suitable to itself, and updates them as needed. When you see "Meets or exceeds such-and-such a standard" on an oil bottle, it means that this oil has passed whatever battery of tests are spelled-out by that standard.

As an example, I was once far from home on my air-cooled two-stroke motorcycle and needed oil. All I could find was an outboard engine oil. Two miles down the road, my engine whiskered a plug. The outboard oil, adequate for well cooled marine service, deposited metal whiskers at higher temperature.

The history of oil standards is a shadow history of engine development. As rpm and specific power have risen, oils have had to steadily improve to keep rings free, protect against seizure, and keep rolling-element bearings happy. The American Petroleum Institute's (API) old 'TC' standard (two-cycle) guarded against seizure with a honey-like petroleum base. It used metallic-based detergents against ring sticking, but these could whisker plugs.

The next standard, TC-W, substituted amide-imide-based detergent/dispersants to keep rings free yet avoid plug whiskering. This was a Boating Industry Assn. (BIA) standard aimed at big, slow-turning, and usually overcooled outboard engines. BIA became the National Marine Mfr's Assn (NMMA, whose TC-W-II gave stronger protection against ring sticking at higher piston temperature. It was phosphorus-free to meet environmental regulations. TC-W-III offers 'excellent lubricity and ring freedom'.

Standards close to what snowmobiles require were set by the Japan Auto Standards Organization (JASO). These test dispersancy (ring freedom), lubricity (seizure resistance), starting torque, smoke formation, and deposit formation.

In the JASO lubricity test, an engine running on the dyno has its coolant flow cut and horsepower loss is measured. This is repeated, and the power drop must fall in a specified range. An engine is run with smaller and smaller oil percentages (60:1, 100:1, then 150:1) yet despite this oil starvation, it must not seize and power must not drop more than a certain percentage. You can see why such testing is expensive. JASO ratings of increasing severity are FA, FB, FC.

The International Standards Organization (ISO) set ISO-L-EGB, which roughly corresponds to JASO FB, and ISO-L-EGC which is close to JASO FC. European experience showed a need for an even higher level of protection against ring sticking, so ISO-L-EGD's dispersancy test runs at high load for three hours instead of the one hour of the JASO-FC. This makes EGD a "Daytona" of ring sticking tests. It is commented that many oils which pass EGD are synthetics.

As you might expect, engine manufacturers keep to the standards set in their regions of origin. Polaris specifies TC-W-III but their "gold" oil also meets JASO FC and ISO-L-EGD. Yamaha support the Japanese JASO-FC standard. Bombardier, whose engines are made in Austria, hold with ISO-L-EGD.

As a careful operator of a snowmobile engine, you will probably never push your powerplant as hard as do the tests in these oil standards. That provides you with a generous margin of safety. Next time you run down that long frozen lake, mile after reliable mile, think of the oil test technicians in the hot dyno rooms, bolting in yet another fresh test engine, mixing fresh fuel with yet another experimental oil formulation. They are working for you.