Understanding Modern 2-Cycle Lubricants

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by Mark Zaic Legend Performance, Inc.

Current production snowmobiles available from today's manufactures represent an advancement in performance and technology. This level of sophistication has resulted from years of continual improvement in manufacturing processes as well as innovative engineering design. The lubricants that protect these high-tech machines have also undergone continual change over the years. These advancements in chemistry have provided better protection and reduced emissions, but as we will learn, not all these changes have produced positive long-term benefits.

This article will describe the history of two-cycle oils, the trend of technology through the years to today's current petroleum and synthetic lubricants and explain how they are chemically engineered. We will also compare the advantages and disadvantages of both types of oils so you can decide for yourself what oil is right for your snowmobile.

First of all, two-cycle oils (abbreviated 2T) differ from four-cycle lubricants (abbreviated 4T) in the fact that 2T lubricants "must combust or burn" and are chemically altered to do so. Four-stroke, 4T oils are designed "not to burn" or combust and have different chemistry profiles that inhibit consumption by the engine. It is therefore for those unique and completely opposite operating requirements that a classification needed to be assigned to differentiate the oils based on the engine design cycle (2 vs. 4 stroke). The NMMA (National Marine Manufactures Association) was the first to set the standards for two-cycle oils (2T) beginning in 1960. Listed below is a timeline for the various ratings:

NMMA Ratings

- TC-W (air cooled) -- 1960-1988
- TC-WII (water cooled) -- 1988-1995
- TC-W3 (water cooled/marine) -- 1992-1996
- Recertified TC-W3 -- 1996-current

As you can see, we are currently under a "recertified" TC-W3 classification for two-cycle lubricants that was driven by some of the OEM's to improve detergency, lubricity and reduce ring sticking. All 2T oils today must meet the TC-W3 rating to be OEM approved and maintain your warranty requirements set forth by the manufacture.

Back in the early 1990's, Japan as a major manufacture of two-strokes, decided it needed it's own standard to rate and develop 2T oils for quality assurance purposes. The API (American Petroleum Institute-USA) was the only automotive standard at the time. This standard did not meet the higher quality testing criteria for oils the Japanese desired as their testing methods were much more severe and wider in scope than the API's TA, TB, TC rating format. On July 1st, 1994, the marketing of JASO (Japanese Automobile Standards Organization) oil began worldwide. Being of a

higher quality requirement than the USA API standard, this provided many developing countries the criteria to formulate and test their lubricants with. Figure 1 illustrates the JASO Standard of classification for 2T oils. JASO classification for 2T oils are FA, FB, FC, FC is the highest JASO rating. Most currently available 2T oils meet the JASO FB rating, only premium 2T oils obtain an FC classification.

JASO TWO-STROKE QUALITY CLASSIFICATION SYSTEM					
Parameter and Test	Test Engine	Fuel:Oil Ratio	JASO Classification		
			FA	FB	FC
Detergency (1 hr) JASO M 341-91	Honda super DIO SK50M	100:1	80	85	95
Lubricity JASO M 340-92		50:1	90	95	95
Initial torque JASO M 342-92			98	98	98
Exhaust smoke JASO M 342-92	Suzuki SX 800 generator	10:1	40	45	85
Exhaust system blocking JASO M 343-92		5:1	30	45	90
Minimum Values Shown Are Based on JATRE-1 Reference Oil, which Equals 100					

Since the inception of the JASO ratings, maturing global standards and requirements driven by the Europeans has created a demand for greater detergency and reduced spark plug fouling for 2T oils over the current JASO FC classification. This brought about the ISO (International Standards Organization) and consequently, the ISO-L-EGD rating for 2T lubricants-Figure 2.

THE GLOBAL SYSTEM OVERLAYS JASO QUALITY CLASSIFICATIONS				
Parameter and Test	ISO Classification			
	N/A	EGB	EGC	EGD
	JASO Classification			
	FA	FB	FC	
Detergancy (3hr)				125
Piston Varnish (3hr)				95
Detergency (1hr) JASO M 341-92	80	85	95	
Piston Varnish	-	85	90	

(1hr)				
Lubricity JAOS M 340-92	90	95	95	95
Initial Torque JASO M 342-92	98	98	98	98
Exhaust smoke JASO M 342-92	40	45	85	85
Exhaust system blocking JASO M 343-92	30	45	90	90
*Mininum values shown are based on JATRE-1 reference oil, which equals 100				

Figure 2 compares JASO and ISO ratings with a "reference oil" with an assigned number between 0 and 100. The higher the number, the better the test 2T oils performance in comparison to the reference oil. As time marches on, more classifications will appear based on OEM, EPA environmental and geo-political mandates. The higher the classification the better the oils will become based on advancements in additive technology and intelligent chemistry. But as we will see later in this article, ***"It's what's NOT in an oil that really counts!!"***

So today, we have NMMA TC-W3, API TA, TB, TC, JASO FA, FB, FC and ISO ISO-L-EGD classifications for 2T lubricants. Any oil you select for your snowmobile must and should fall into the minimum TC-W3 rating as noted on the container. Higher quality petroleum and synthetics 2T oils will be classified as API TB, TC, JASO FB, FC or ISO-L-EGD types.

Fortunately, most oils today meet these strict requirements, but snowmobile engines require different chemistry than boats and other two-stroke applications to provide the higher BMEP (Brake Mean Effective Pressures) and horsepower output the modern snowmobile powerplant is capable of producing. Snowmobile engines generate a higher specific power output per cc (cubic displacement in centimeters) than most engines and at a higher sustained rpm. Cold operating temperatures and air-cooled vs. liquid-cooled adds to the fray as to which formulation will provide the best protection and low temperature pour point/fluidity. As you can see, our beloved snowmobiles challenge reliable operation by operating in a severe environment that most two-strokes won't have to deal with.

Back in the 1960's and 1970's a 20:1 fuel/oil ratio was common. In the late 1970's and early 1980's 30 & 40:1 ratios become more the trend. This gradually evolved into a 50:1 which is today and has been the standard pre-mix ratio recommend by most manufactures and oil blenders. For racing or all-out performance, there are 100:1 ratios available that will give the best engine response and protection by minimizing octane dilution of the fuel. These "leaner" oil ratios are fully synthetic (ester or di-ester) formulas and can be engineered to meet the demands of high rpm/extreme load operation.

With oil injection systems standard on most every production snowmobile today, pre-mixing is generally reserved for racing only. Not all two-cycle oils are formulated for pre-mix applications and only premium 2T oils can be used for both forms of lubrication. When pre-mixing the oil, the ratio of gas to oil is the same at all RPMs.

Only the best lubricants with advanced chemistry and additive technology can burn at the "richer" oil to fuel ratios in pre-mix applications.

Today, many snowmobile engines are designed with power valves to enhance the low and midrange performance. This requires an oil to be exceptionally clean burning to prevent the "gumming-up" and eventual sticking of the power valves in the open or closed position. This is one reason the OEM's recommend expensive synthetic oils to help reduce valve sticking and contamination. The majority of synthetics tend to burn cleaner because they are not a fossil derived petroleum by-product, rather a man-made chemically designed molecule.

Modern synthetics have advantages over most petroleum based 2T oils in the areas of high rpm protection, lower sub-zero pour point, cleaner burning with less smoke, lower carbon deposits on pistons, rings and power valves. The most notable disadvantages of synthetics are high price, poor off-season rust protection, irritating smell along with eye and respiratory discomfort due to the solvents used in manufacturing and loss of ring seal due to "glazing" of the cylinder walls with extended use. After several years of intensive research, we have documented that the use of synthetic 2T oils will in fact cause the cylinder walls to "glaze over" and cause "blow-by" at the piston rings eventually resulting in a power loss. This will be evident when you remove a cylinder and find discoloration below the ring lands most notably on the piston sides. Our research has determined this begins around 1500-1800 miles and worsens with continued use of synthetics. Why all the hype then about synthetics? And why do the manufactures urge you to use them?

The synthetic molecule by virtue of design is "chemically" superior to the petroleum molecule. The real benefit of a man-made synthetic molecule occurs at extreme high RPMs. When the reciprocating loads and heat saturation limits reach engine component failure levels (10-12,000+ rpm), synthetics provide the needed protection. This level of operation is rarely ever seen in snowmobiling today except in drag racing or full-mod engines tuned for maximum performance. The disadvantages of synthetics, namely the unacceptable loss of ring seal with continued use, poor off-season rust protection for the crankshaft bearings from ever present internal moisture and unpleasant exhaust fumes far outweigh the advantages. Most people expect when paying 30-50% more for an oil to get something for their investment, not a loss of performance or an expensive repair bill when they lose a crank bearing at the beginning of the season caused by internal rust.

Manufactures insist on using synthetics because they lack the technology to blend a petroleum 2T oil that will burn clean and not cause pre-mature power valve sticking. Cleaning power valves is a drag and the OEM's realize that most people would rather ride than spend time doing maintenance caused by a poor grade of oil. Blending oil is an art, a skillful balance of chemistry and component selection along with additives that perform in a predetermined manner. This art is referred to as "chemical engineering" and unfortunately do you rarely find a professional engine builder working closely and in conjunction with a qualified lubricants chemist.

Petroleum or mineral based 2T oils have more advantages than disadvantages: They provide superior off-season rust protection because mineral oils are natural lubricants, not man-made, they are affordable and provide good all-around performance without destroying piston ring seal by glazing the cylinder walls. Their

disadvantages are that they are not as clean burning as synthetics, and some will not provide the film strength in "extreme" high rpm load or heat conditions.

What would be the "preferred" two-cycle lubricant is combining the best features of both mineral based oil and a synthetic with the undesirable traits chemically altered or removed to obtain the best of both worlds. This "hybrid" 2T formula would be an ultra-pure, highly refined, superior quality base oil combined with an additive package that would offer all the benefits in film strength and cleanliness of a synthetic yet still be classified as mineral oil. The good news is this technology exists, yet very few people understand the importance and the balance of chemistry to make it a reality.

To understand this concept, let's look at what 2T oils are made from.

Figure 3 represents the basic formula structure for current petroleum and synthetic oils. The chart on the left illustrates typical mineral base oils and on the right synthetics.

Traditional Oil Quality		**OEM Recommended Quality**
ISO-EGB/JASO FB/API TC or JASO FA/API TA/API TB		API TC / ISO-EGC / JASO FC ISO-EGD
DI Additive		Balanced DI System
Brightstock		PIB
Heavy Neutral Basestock		Heavy Neutral Basestock
Minimal Solvent Level		Higher Solvent Level

Notice the use of PIB (poly-iso-butane) instead of bright stock and the higher solvent content in the synthetic 2T oils. PIB does contribute to lubricity with "anti-scuffing" properties. The PIB is part of the man-made synthetic molecular structure that inhibits ring seal on engine "break-in" and leads to glazing of the cylinder walls. The reason for this lies in the fact that some of the synthetic molecules "high molecular weight" and chemical compounds (sulfur) cannot combust completely and thereby leave a residue on the cylinder wall. This residue continues to build over time and ' eventually prevents the rings from making contact with the cylinder walls leading to blow-by. This condition deteriorates performance and can be corrected only by honing the cylinder walls and installing fresh piston rings or switching to a high quality mineral based lubricant.

The higher solvent content in synthetics not only drive up the cost, but contribute to the typical "foul odor" and incomplete combustion based on improper solvent selection. The DI (detergency) portion of the formula controls the oils ability to minimize residue and build-up on internal components. While the charts show what would be an ideal progression towards improved lubricant performance, the basic ingredients used in blending of 2T oils and the "closeminded" approach by most chemist has prevented technological advances in oil formulation. As engine technology improves so should the lubricants, this has not been the case with two-cycle synthetics.

What must take place is a change of attitude from: 'It's worked in the past, it should work now' chemistry to a mentality of: 'If it worked in the past there must be plenty

of room for improvement'. Then we can move forward and conduct an in-depth research of modern combustion engines, the effect of lubricants in a "post-combustion" atmosphere and "chemically engineer" the lubricant to perform without the compromise typical in today's 2T oils. The successful art of blending a "hybrid" ultra-performance lubricant is a balancing act of chemistry: "Quality In = Quality Out." Premium quality ingredients, advanced additive technology and an experienced team of professionals working together will produce a better class of lubricant for extreme conditions.

Legend Performance & Technologies, Inc. has led this change and has accomplished our mission in blending a mineral based two-cycle oil with synthetic-plus performance. While most oil companies and OEM manufactures blend their oils to achieve a certain level of engine reliability for warranty purposes and a "price point" for attractive sales, we at Legend Performance do quite the opposite. Listed below is a comparison of blending practices compared to the innovative approach used by Legend Performance.

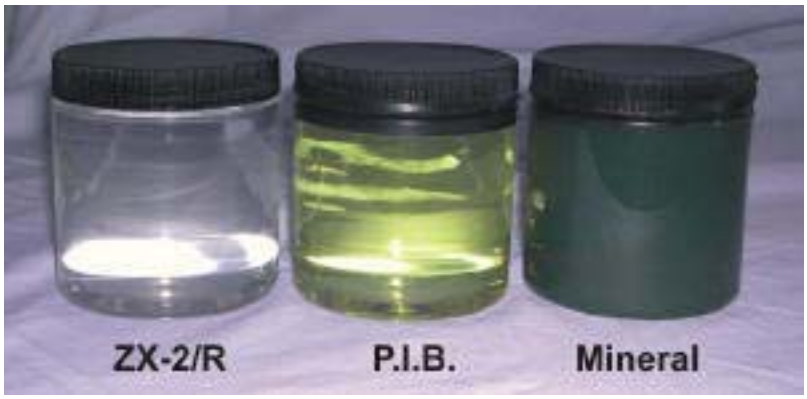
Blending Practices
Traditional Technology vs. Innovative Technology

Aftermarket / OEM 2T Oils	Legend ZX-2 / ZX-2R
Basestocks	
Average quality base oils- adds cost / higher profit. Most are high ash content-contributes to carbon, deposits and higher exhaust emissions	Ultra-high quality "pure ashless" base oils-maximum purity, internal cleanliness, lubricity and protection adds cost, reduces exhaust emissions
Solvents	
High solvent content-more profit with higher exhaust emissions, post-combustion smoke and odor	Select quality solvent content for cold weather fluidity and desired flash point. Reduces cost / lower exhaust emissions smokeless, odorless
Additive Package (DI, Brightstock, PIB,etc.)	
Higher additive "treat-rate" to obtain TC-W3 rating due to lower the quality base oils, adds cost / raises exhaust emissions	Superior proprietary additive technology, controls cost due to lower "treat-rates" by use of the highest quality ultra-refined base oils. Lowers cost / exhaust emissions
Add PIB's to synthetics replacing Brightstock, adds significant cost with slightly enhanced cleanliness. Promotes high rpm protection	Balance Brightstock with proprietary blend of "chemically engineered" molecules to obtain synthetic quality protection-lowers cost, provides high rpm protection

After comparing traditional vs. innovative blending practices and philosophies, then comparing the differences, it becomes obvious that Legend Performance, Inc. has produced a superior formulation that is petroleum-based. We have achieved our goal by combining the best of both chemistries through a "common sense" approach. By using the most advanced additive technologies available in the world, we have created 2T lubricants which out-perform the best synthetics at a mineral oil price! By investing in the best quality base oils then refining to an "ultra pure" state combined with a chemically advanced additive package, we develop what is called a hybrid

rates and expensive synthetic additives, we produce a superior lubricant at a lower cost to the consumer.

The ZX-2 / ZX-2R formulas are engineered to completely combust with minimal if any deposits after combustion. Synthetics and conventional mineral oils produce by-products of combustion due to their chemistry content. Figure 4 shows the visible difference between a mineral, synthetic and the ZX-2 / R base stocks refined purity.



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The ZX-2R base oils are "super-refined" to a "turbine oil" pureness. With the higher molecular weight, low energy, poorly combustible constituents (tar, asphalt, waste minerals, etc) refined out, we are left with a more "pure" natural lubricant. It is this combination of base stock quality and advanced additive technology that provides the oil its lubricity or the level in which it is capable of protecting your engine.

The "cleaner" a 2T oil can burn, the less octane it requires from the fuel to combust, thereby leaving more octane available for performance.

Figure 5 shows the "post combustion" results on pistons along with mileage documentation.

CLICK IMAGE FOR LARGER VIEW

Synthetic "blends", which as the name implies are a blend of mineral oil base stocks with synthetic "fortifiers" added to improve protection and cleanliness at a lower price than full synthetics. Again, the chemistry is complicated in achieving the ideal balance between petroleum and synthetic. Our testing has shown most synthetic blends fall short of any worthwhile improvement for the higher price they demand.

In the future, with more stringent protocol for lower global emissions from our venerable two-stroke powerplants, governing entities will dictate the acceptable emission levels. Manufactures are now responding with Direct Injection and

four-strokes engines to help lower exhaust pollution. At Legend Performance, we have taken steps to do our part in developing "state of the art" hybrid lubricants that will contribute to lower exhaust emissions and boost performance while providing maximum engine protection.

Legend Performance, Inc., in conjunction with SUNY Canton (State University of New York) conducted exhaust emissions testing on a 500cc two-stroke snowmobile engine in February 2003. The results from the test proved the ZX-2R formula produced lower exhaust emissions than the leading "synthetic" oils and provided better throttle response as noted by the SUNY staff. While fuel management is responsible for the majority of emissions, 2T oil does have an effect as demonstrated by our testing.

The technology is now available to extend your engine life dramatically while virtually eliminated carbon deposits and internal rust or corrosion. The best part? No longer any compromises in which oil to choose from: mineral or synthetic? Or the higher price for cleanliness.

ZX-2 / ZX-2R have been developed for the most demanding riders, trail or race and are hybrid "super" lubricants that provide the ultimate protection and internal cleanliness. Now you understand why: ***"It's what's NOT in oil that really counts!!"***