TECHNICAL STUDY

AMSOIL
The First in Synthetics®

A Study of INTERCEPTOR® Synthetic 2-Stroke Oil for Ski-Doo® Rotax® E-TEC® Engines

With ASTM Lubricity and Detergency Testing

Published November 2012

Overview

Direct fuel injection (DFI), sophisticated computer programming, targeted electronic oil injection and other developments have enabled a new era in two-stroke powersports engine design. Modern engines offer an unprecedented combination of increased power, improved fuel efficiency and reduced emissions.

The increased level of performance comes at a price: Modern engines encounter increased heat, friction and stress while often using less oil to lubricate and protect vital engine parts. The Rotax E-TEC 800R, for example, is a liquid-cooled, DFI two-stroke engine capable of 7,900 rpm and 163.9 hp. It incorporates electronic equipment that can adjust the amount of oil the engine uses depending on operating conditions. As a result, the engine produces fewer exhaust emissions, but undergoes increased severity. Durable oils formulated to provide increased lubricity are best suited for powersports engines like the Rotax E-TEC 800R.

Objective

Compare the ability of AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil and XPS-2 Synthetic 2-Cycle Oil to protect against engine wear and deposits in a snowmobile equipped with a Rotax E-TEC 800R engine. Further compare the lubricity and detergency properties of each oil using industry-standard American Society of Testing and Materials (ASTM) testing. Demonstrate that INTERCEPTOR exceeds the performance requirements of high-performance DFI snowmobile engines in severe operating conditions.

Note: XPS-2 Synthetic 2-Cycle Oil (batch code 071 11 208), obtained in December 2011, and AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil (batch code 14631347) produced December 12, 2011 underwent testing completed in March 2012. Both oils were available to consumers at the time of testing. Test results do not represent future formulation changes. This test data reflects single test runs, and statistical repeatability was not determined.

Methodology

AMSOIL developed the extreme dynamometer test on Rotax E-TEC engines in order to determine each oil's level of engine protection. Following each 50-hour procedure, the engine was disassembled and the components rated by an ASTM calibrated rater. Merit ratings for each set of components (e.g. piston skirts, piston rings, etc.) were determined using the appropriate techniques and rating scales as defined in the Coordinating Research Council, Inc. *Deposit Rating Manual No. 20*. Some components received a merit rating based on a 1-10 scale, with 10 representing a component free of defects and 0 representing catastrophic distress. Others received merit ratings indicating the percentage of an area with defects (e.g. the percentage piston skirt area containing scuffing).

The lubricity properties of each oil were compared using the Standard Test Method for Determination of Lubricity of Two-Stroke/Cycle Gasoline Engine Lubricants (ASTM D 4863 Mod.). The detergency properties of each oil were compared using the Standard Test Method for Determination of the Ability of Lubricants to Minimize Ring Sticking and Piston Deposits in Two-Stroke/Cycle Gasoline Engines Other than Outboards (ASTM D 4857 Mod.). In both ASTM tests, the reference oil was replaced by XPS-2 Synthetic 2-Cycle Oil to establish a performance benchmark and facilitate a direct comparison. Both ASTM tests were performed by an independent lab.

Extreme Dynamometer Test on Rotax E-TEC Engines

The Extreme Dynamometer Test on Rotax E-TEC Engines subjected a candidate oil to 50 hours of engine dyno testing—sufficient time to simulate a full season of snowmobile riding. Each 50-hour procedure included periodic breaks to refuel and overnight periods of inactivity to simulate real-world operation. Following collection and dissemination, all data was compared to determine each oil's level of performance.

Test Snowmobile
The candidate oil was installed in a 2012 BRP Ski-Doo Renegade X snowmobile equipped with a Rotax E-TEC 800R engine. The snowmobile was purchased new from an authorized BRP dealer.

Engine Dynamometer
The snowmobile was connected to a Land and Sea DYNOmite™ engine dynamometer equipped with a 9-inch water-cooled centrifugal pump water brake capable of absorbing 200 hp. The dyno was first calibrated using the test snowmobile to ensure the most accurate results possible. Throttle position and load control were strictly controlled via computer. Data was gathered using DYNOmite Pro Data Acquisition Software. The dyno uses water under pressure to place load on the motor, simulating the torque produced by a snowmobile's continuously variable transmission.

Pre-Test Procedure
As is standard practice, the dyno was first calibrated along with the test snowmobile prior to testing. Following calibration, the snowmobile's engine was refreshed with new cylinders, cylinder heads, pistons, rings, wrist pins and wrist pin bearings using only authorized BRP replacement parts and standard engine-building practices to ensure operation time during calibration did not affect final results.

To ensure accuracy, variables including fuel quality, coolant mixture ratio, rpm and engine load were controlled from one 50-hour procedure to the next. The main cooling unit controlled engine temperature via the factory pre-set thermostat. Per BRP's specifications, a 50/50 mixture of coolant and water was used. For additional control purposes and to further limit variables, engine parts were measured before and after each dyno procedure. (Pre- and post-test measurements are included in Appendix A.) The snowmobile's ECM was not modified in any way.

Care was taken to replicate real-world operating conditions while conforming to BRP's recommendations given in the snowmobile owner's manual. The same batch of pump gas was used throughout testing. The gas met BRP's specifications of a minimum 91 octane rating and a maximum ethanol content of 10 percent (see Appendix B). Gas containing 10 percent ethanol was used because it increases engine stress compared to gas with reduced ethanol content, representing a worst-case scenario that further challenges each oil.

50-Hour Dyno Procedure
With the engine prepared, a candidate oil was installed in the snowmobile's oil tank to the 3/4 mark and the fuel tank filled to the bottom of the filler neck.

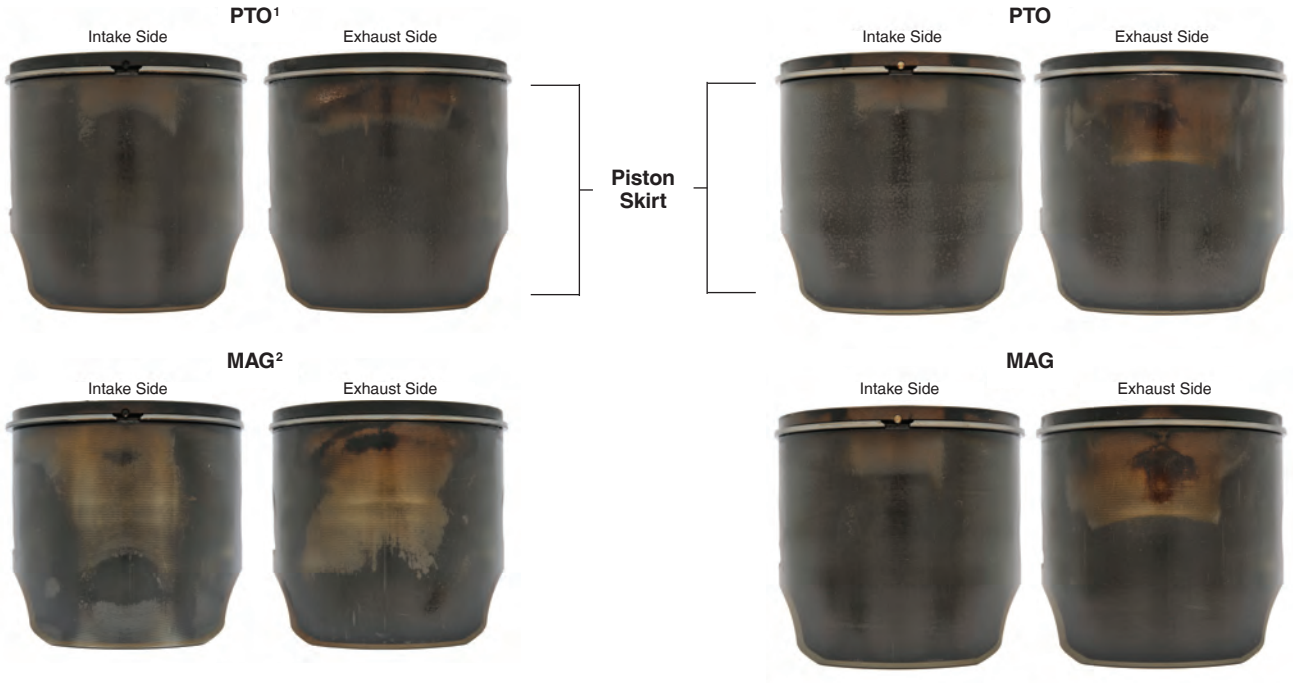
To supplement the traditional dyno cooling tower and to further simulate the cooling effects of snow in actual use, an auxiliary spray bar directed a controlled amount of water on the front and rear heat exchangers. A high-speed fan was positioned to provide additional air underneath the snowmobile's hood, simulating airflow in real-world riding conditions. Once the engine reached 100°F, the automated dyno program was activated.

Each dyno procedure was conducted according to the same computerized script. The engine underwent break-in according to its pre-programmed ECM, which was reset prior to conducting the second procedure. The dyno program required the engine to undergo all types of operating conditions, including idle time, partial-throttle operation and full-throttle operation. Maximum rpm (7,900 ± 100) was repeatedly run during each procedure and exhaust gas temperatures often surpassed 1,200°F, illustrating the severity of operation.

Once the 50-hour dyno procedure was complete, the engine was disassembled. The parts were again measured and the post-test measurements documented. The parts were rated for wear and other distress by an ASTM calibrated rater. The complete upper end of the engine was again refreshed in preparation for the next 50-hour procedure.

Results of Extreme Dynamometer Test on Rotax E-TEC Engines

Pistons



XPS-2 Synthetic 2-Cycle Oil

Piston Scratching, PTO	3%
Piston Scratching, MAG	1%
Piston Scuffing, PTO	0%
Piston Scuffing, MAG	0%
% Coating Removed, Exhaust Side, PTO	5%
% Coating Removed, Intake Side, PTO	5%
% Coating Removed, Exhaust Side, MAG	45%
% Coating Removed, Intake Side, MAG	35%

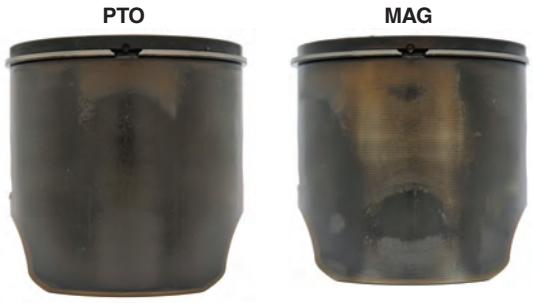
AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Piston Scratching, PTO	2%
Piston Scratching, MAG	3%
Piston Scuffing, PTO	0%
Piston Scuffing, MAG	0%
% Coating Removed, Exhaust Side, PTO	20%
% Coating Removed, Intake Side, PTO	5%
% Coating Removed, Exhaust Side, MAG	25%
% Coating Removed, Intake Side, MAG	10%

Scratching, which is not lubricant-related, refers to the alteration of the skirt surface by fine particles suspended in the lubricant, fuel, air or embedded in a surface. Scuffing is lubricant-related and appears as a matte finish. Both oils completely prevented piston skirt scuffing. The pistons are manufactured with a coating that is black in color. INTERCEPTOR effectively protected pistons from wear and limited removal of the black coating.

[1] Power take off side
[2] Magneto side

Piston Rings & Lands



XPS-2 Synthetic 2-Cycle Oil

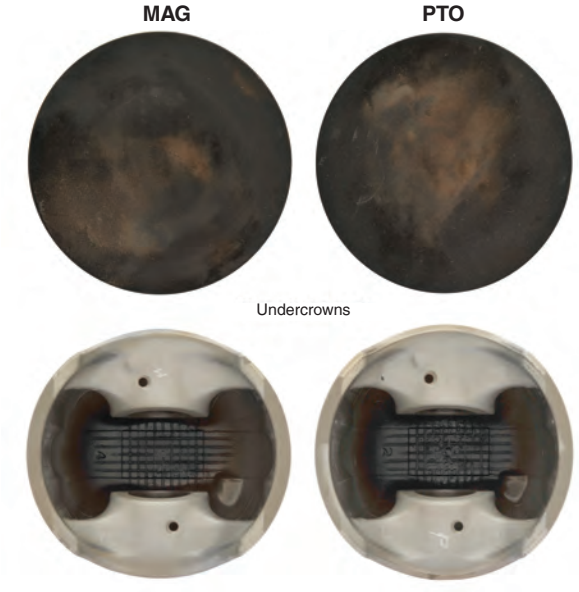
Ring Sticking, PTO	10
Ring Sticking, MAG	10
Crown Land, PTO	0.64
Crown Land, MAG	0.75

AMSOIL INTERCEPTOR
Synthetic 2-Stroke Oil

Ring Sticking, PTO	10
Ring Sticking, MAG	10
Crown Land, PTO	1.83
Crown Land, MAG	2.30

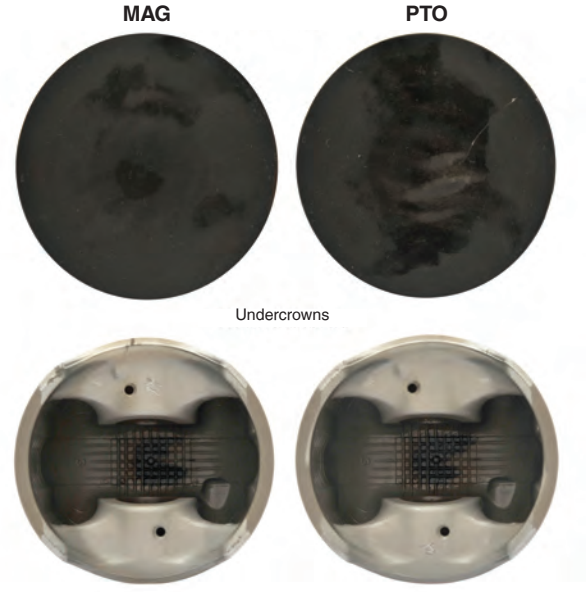
Piston ring deposits can cause ring sticking and consequent power loss. The rings in both engines earned perfect 10 merit ratings, demonstrating each oil prevented sticking.

Piston Crowns & Undercrowns



XPS-2 Synthetic 2-Cycle Oil

Piston Crown, PTO	8.39
Piston Crown, MAG	8.25
Undercrown, PTO	2.66
Undercrown, MAG	3.48

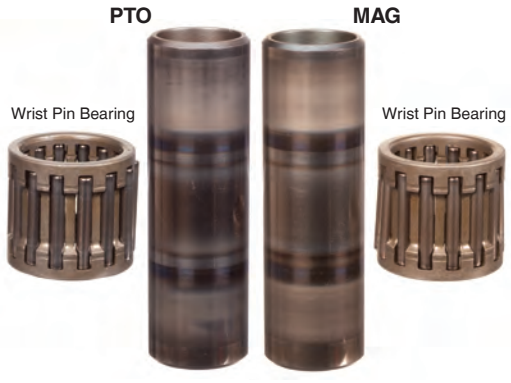


AMSOIL INTERCEPTOR
Synthetic 2-Stroke Oil

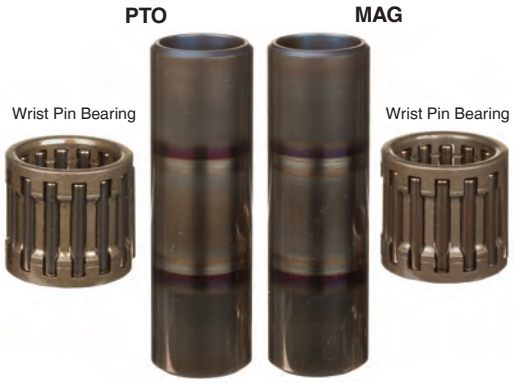
Piston Crown, PTO	8.48
Piston Crown, MAG	8.45
Undercrown, PTO	7.76
Undercrown, MAG	7.90

To protect against pre-ignition and poor performance, two-stroke oils must resist piston crown deposits caused by the elevated temperatures inside the combustion chamber. Piston crowns in both engines earned high ratings for deposits, with INTERCEPTOR earning high ratings for undercrown deposits as well.

Wrist Pins & Bearings



XPS-2 Synthetic 2-Cycle Oil



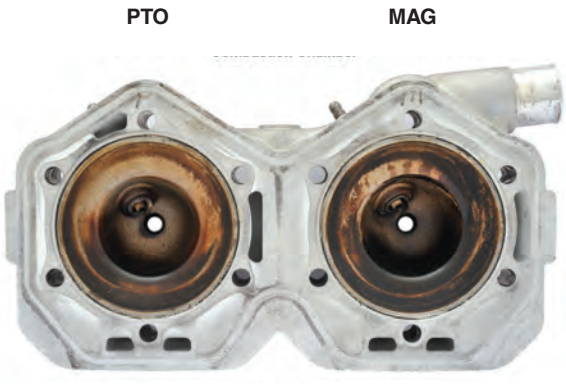
AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Piston Wristpins, PTO	4.90
Piston Wristpins, MAG	5.30
Piston Wristpin Bearing, PTO	8.05
Piston Wristpin Bearing, MAG	8.35
Wristpin Case Condition, PTO	Good
Wristpin Case Condition, MAG	Good

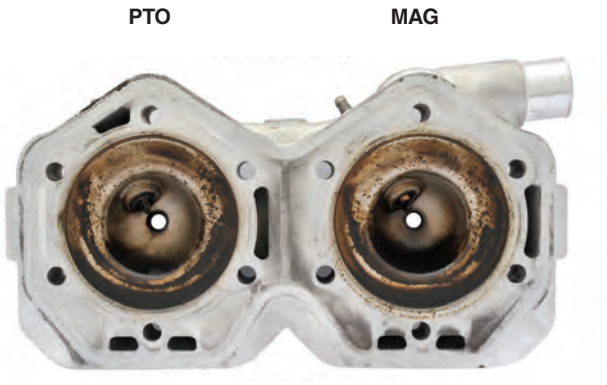
Piston Wristpins, PTO	6.80
Piston Wristpins, MAG	7.30
Piston Wristpin Bearing, PTO	8.92
Piston Wristpin Bearing, MAG	8.92
Wristpin Case Condition, PTO	Good
Wristpin Case Condition, MAG	Good

The wrist pins and bearings undergo constant rotational stress and represent areas prone to metal-to-metal contact and wear. The oil must maintain its lubricating film for optimum protection. INTERCEPTOR limited wear effectively and provided a high level of protection.

Cylinder Heads



XPS-2 Synthetic 2-Cycle Oil



AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Cylinder Head, PTO	9.37
Cylinder Head, MAG	9.09

Cylinder Head, PTO	9.10
Cylinder Head, MAG	9.04

Excessive cylinder head deposits are undesirable and can negatively affect performance. Both oils demonstrated strong cleanliness properties.

Intake Ports & Cylinders

PTO MAG PTO MAG

XPS-2 Synthetic 2-Cycle Oil

Intake Port, PTO	9.90
Intake Port, MAG	9.90
% Scratching, PTO	1%
% Scratching, MAG	1%
% Cross Hatch Removed, PTO	1%
% Cross Hatch Removed, MAG	1%
Rating, PTO	9.66
Rating, MAG	9.66

AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

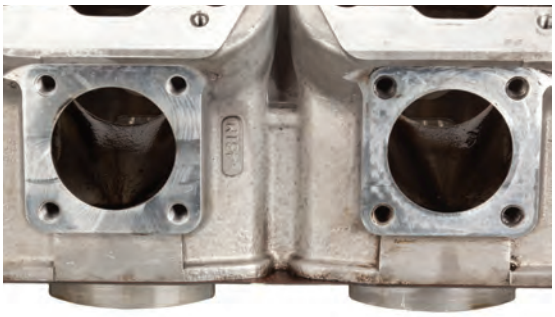
Intake Port, PTO	9.89
Intake Port, MAG	9.89
% Scratching, PTO	1%
% Scratching, MAG	1%
% Cross Hatch Removed, PTO	1%
% Cross Hatch Removed, MAG	1%
Rating, PTO	9.70
Rating, MAG	9.70

Intake port deposits in both engines were virtually non-existent. Both oils inhibited cylinder bore wear extremely well, demonstrating strong wear protection. Overall merit ratings were high for both sets of cylinders.

Exhaust Ports

XPS-2 Synthetic 2-Cycle Oil

Exhaust Port, PTO	8.80
Exhaust Port, MAG	8.70
% Blockage, PTO	1%
% Blockage, MAG	1%



AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Exhaust Port, PTO	9.54
Exhaust Port, MAG	9.54
% Blockage, PTO	1%
% Blockage, MAG	1%

Excessive exhaust port deposits and blockage restrict airflow and contribute to poor performance. Both oils demonstrated strong cleanliness properties as demonstrated by the high merit ratings for deposits and virtually no port blockage.

Exhaust Power Valves

PTO Top

PTO Top

PTO Bottom

PTO Bottom

XPS-2 Synthetic 2-Cycle Oil

AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

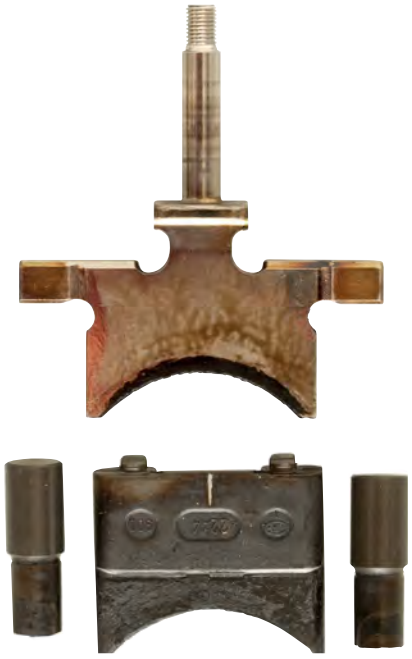
Excessive hard carbon deposits and varnish on the exhaust power valves can interfere with operation, reducing engine performance. None of the exhaust power valves tested exhibited any sticking, indicating both oils provided strong cleanliness properties.

Exhaust Power Valves

MAG Top

MAG Top

MAG Bottom



MAG Bottom

XPS-2 Synthetic 2-Cycle Oil

AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Results of the Standard Test Method for Determination of Lubricity of Two-Stroke/Cycle Gasoline Engine Lubricants (ASTM D 4863 Mod.)

Whether using a gas/oil pre-mix or direct oil injection, two-stroke engines can operate for short periods with less oil than is desirable. In direct-oil-injected engines, throttle bursts can also result in the engine operating with reduced oil for short periods. The oil's lubricity is vital to protecting against piston and cylinder scuffing under these operating conditions.

The ASTM D 4863 lubricity test evaluates the ability of a lubricant to minimize piston and cylinder bore scuffing in two-stroke, spark-ignition gasoline engines. The engine is operated at a 150:1 gas-to-oil ratio—much leaner than the ratios used by Rotax E-TEC engines.

A reference oil is run in a Yamaha CE50S 50cc engine at wide-open throttle. The cooling fan is then shut off, allowing the engine temperature to increase. Heat causes piston expansion, causing friction to increase and torque to decrease. The torque value of the reference oil at three different temperatures is recorded. The candidate oil undergoes the same procedure, and its torque value at the same temperatures is recorded. Greater torque loss means lower power and less lubricity. The torque reduction value at 662°F must be equal to or below the corresponding value for the reference oil in order to receive a passing grade. In short, lower values mean better lubricity. General engine condition is evaluated at the end of the test.

To facilitate a direct comparison, the benchmark reference oil was replaced by XPS-2 Synthetic 2-Cycle Oil.

Temperature (F°)	XPS-2 Synthetic 2-Cycle Oil (Reference)	AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil
572	3.23 lb. in.	2.83 lb. in.
617	4.00 lb. in.	3.62 lb. in.
662	4.79 lb. in.	4.42 lb. in.

Torque values for INTERCEPTOR were lower than the corresponding values for XPS-2 Synthetic 2-Cycle Oil. INTERCEPTOR demonstrated strong lubricity properties and surpassed the benchmark for lubricity at the 95 percent confidence level.

Results of the ASTM TC Sequence I Detergency Test (ASTM D 4857 Mod.)

High-temperature, high-rpm two-stroke engines are susceptible to the effects of lubricant failure. Piston ring sticking, deposits and varnish can cause difficult starts and decreased operating efficiency. The lubricant's detergency properties are critical to resisting harmful deposits and varnish.

The ASTM D 4857 detergency test is designed to evaluate the cleanliness properties of a two-cycle engine lubricant. Particular attention is paid to piston skirt varnish, piston ring sticking, spark plug fouling, pre-ignition, combustion chamber deposits and exhaust port blocking. Testing is done at a 50:1 gas-to-oil ratio.

The test uses a Yamaha RD350B 347cc engine designed to operate with a reference oil in one cylinder and a candidate oil in the other. After 20 hours of run time, the engine is disassembled and rated for deposits, ring sticking and other distress.

To facilitate a direct comparison, the benchmark reference oil was replaced by XPS-2 Synthetic 2-Cycle Oil.

Cylinder Heads

XPS-2 Synthetic 2-Cycle Oil

Cylinder Liner Wear	10.0
Cylinder Head Deposits	8.7

AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Cylinder Liner Wear	10.0
Cylinder Head Deposits	7.7

Both oils prevented cylinder liner wear and inhibited cylinder head deposits, with XPS-2 Synthetic 2-Cycle Oil earning a high rating.

Pistons & Rings

Thrust

Thrust

Anti-Thrust

Anti-Thrust

XPS-2 Synthetic 2-Cycle Oil

Piston Scuffing, Thrust	10.0
Piston Scuffing, Anti-Thrust	10.0
Piston Varnish, Thrust	9.2
Piston Varnish, Anti-Thrust	8.9
Ring Land	3.0
Ring Sticking, Top Ring	10.0
Ring Sticking, Second Ring	8.4
Piston Crown Deposits	8.0

AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil

Piston Scuffing, Thrust	10.0
Piston Scuffing, Anti-Thrust	10.0
Piston Varnish, Thrust	9.8
Piston Varnish, Anti-Thrust	9.3
Ring Land	6.1
Ring Sticking, Top Ring	10.0
Ring Sticking, Second Ring	8.7
Piston Crown Deposits	7.9

Both oils prevented piston skirt scuffing and ring sticking to the top ring, earning perfect merit ratings. Piston varnish ratings were also high, while INTERCEPTOR earned a high rating for ring land deposits. INTERCEPTOR met or surpassed the performance benchmark in nearly every category.

Conclusion

Testing proves the effectiveness of AMSOIL INTERCEPTOR® Synthetic 2-Stroke Oil in Rotax® E-TEC® engines specifically, and high-performance DFI powersports engines in general. Following 50 hours of engine dyno testing, merit ratings assigned to components by an ASTM calibrated rater offer convincing proof of performance, with INTERCEPTOR earning perfect ratings for piston skirt scuffing and piston ring sticking. Ratings for cylinder bore cross hatch removal, exhaust port blocking and other areas were high and reflect the oil's ability to control deposits and inhibit wear. INTERCEPTOR exceeds the performance requirements.

The results of the ASTM D 4863 lubricity test provide additional proof of performance. At a 150:1 gas-to-oil ratio — far leaner than the ratios produced by the Rotax E-TEC 800R engine — INTERCEPTOR demonstrated increased lubricity compared to XPS-2 Synthetic 2-Cycle Oil and surpassed the performance benchmark. In addition, INTERCEPTOR prevented piston skirt scuffing and cylinder wear and showed strong detergency properties in the ASTM D 4857 detergency test, surpassing XPS-2 Synthetic 2-Cycle Oil as the performance benchmark in almost all instances.

These results have also been confirmed in a 3,469-Mile Rotax E-TEC Engine Case Study (G3038). Pistons taken from a 2011 Ski-Doo TNT snowmobile equipped with a Rotax E-TEC 800R engine exhibited no scuffing or ring sticking following 3,469 miles of real-world, aggressive trail riding.

Based on the results of the Extreme Dynamometer Test on Rotax E-TEC Engines, AMSOIL guarantees that INTERCEPTOR Synthetic 2-Stroke Oil effectively lubricates Rotax E-TEC engines and is a high-performance replacement for BRP's more-costly XPS-2 Synthetic 2-Cycle Oil.

The right to use AMSOIL INTERCEPTOR in Rotax engines without voiding the warranty is protected under U.S. federal law by the Magnuson Moss Warranty Act of 1975. AMSOIL additionally warrants the use of INTERCEPTOR in all Rotax engines according to the AMSOIL Limited Warranty (G1363).

Appendix A: Pre- and Post-Test Measurements

	XPS-2 Synthetic 2-Cycle Oil Batch Code: 071 11 208		AMSOIL INTERCEPTOR Synthetic 2-Stroke Oil Batch Code: 14631347	
	Pre-Test	**Post-Test**	**Pre-Test**	**Post-Test**
Cylinder, Magneto Side (MAG)				
Bore at Top of Ring Travel Diameter (inches)	3.226	3.226	3.226	3.226
Bore at Bottom of Ring Travel Diameter (inches)	3.226	3.226	3.226	3.226
Compression (psi)	150	150	140	150
Cylinder, Power Take Off Side (PTO)				
Bore at Top of Ring Travel Diameter (inches)	3.226	3.226	3.226	3.226
Bore at Bottom of Ring Travel Diameter (inches)	3.226	3.226	3.226	3.226
Compression (psi)	150	150	140	150
Piston, Magneto Side (MAG)				
Diameter (inches)	3.221	3.217	3.221	3.221
Piston Clearance (inches)	0.005	0.009	0.005	0.005
Piston Weight, without ring (g)	462.3	462.5	473.1	473.8
Piston Ring End Gap (inches)	0.019	0.019	0.019	0.019
Piston Ring Weight (g)	9.7	9.7	9.5	9.8
Wrist Pin Weight (g)	100.8	100.7	100.5	100.5
Wrist Pin Bearing Weight (g)	31.7	31.6	31.8	31.8
RAVE Valve, Magneto Side (MAG)				
Weight (g)	317	317	315.6	316.5
Piston, Power Take Off Side (PTO)				
Diameter (inches)	3.221	3.219	3.221	3.221
Piston Clearance (inches)	0.005	0.007	0.005	0.005
Piston Weight, without ring (g)	471.7	471.1	472.1	472.5
Piston Ring End Gap (inches)	0.019	0.019	0.019	0.019
Piston Ring Weight (g)	9.7	9.7	9.8	9.9
Wrist Pin Weight (g)	100.9	100.8	100.8	100.9
Wrist Pin Bearing Weight (g)	31.7	31.7	31.8	31.8
RAVE Valve, Power Take Off Side (PTO)				
Weight (g)	317	317	317.1	318

Appendix B: Fuel Specifications

RON (Research Octane Number)	96.2
MON (Motor Octane Number)	87.2
R+M/2 (RON + MON/2)	91.7
EtOH (Ethanol)	10.2%
Benzene	0.48%
Toluene	2.0%
Paraffins	64.7%
Olefins	6.2%
Aromatics	18.6%

Contact your AMSOIL Dealer for more information on AMSOIL products or to place an order. You may also order direct by calling AMSOIL INC. at 1-800-956-5695 and providing the referral number listed here. ▼

Referral #_____

AMSOIL INC., 925 Tower Ave., Superior, WI 54880 • 715-392-7101 • Printed in U.S.A.