^{z}Max Micro-lubricant -- the Facts

[Revised]

November 13, 2010

^{Z}Max, a commercialized metal interface treatment, is a uniquely processed mineral oil that has demonstrated its ability to ***improve fuel economy***, ***reduce engine deposits***, and ***reduce wear*** through the process of micro-lubrication. This micro-lubrication improves performance by reducing engine friction, affording an attendant improvement in fuel economy, and reducing engine wear and deposits in critical high temperature sealing areas. Because this uniquely processed mineral oil is able to both adsorb onto and absorb (penetrate) into the pores, cracks, and fissures in the engine's metallurgy, a new mechanism of micro-lubrication is offered for improving the overall lubrication and performance in automotive engines.

^{Z}Max is derived from a highly refined mineral oil that undergoes a proprietary process involving specific molecular rearrangement. It has a kinematic viscosity of 11.5 cSt @ 40 °C and 3.00 cSt @ 100 °C, a Surface Tension of 27.75 dynes/cm @ 20°C, and an API gravity of 36.6. A comparison of the high temperature distillation results of ^{Z}Max versus the mineral oil used for its production reveal ^{Z}Max having a slightly higher boiling range than the originating mineral oil. Chemical analyses using gas chromatography and mass spectroscopy conducted by Triton Analytics Corporation (Houston, TX) show a greater concentration of linear hydrocarbon chains in ^{Z}Max than in mineral oil.

Since ^{Z}Max is added to the engine oil, a misconception may exist that ^{Z}Max is an additive for engine oils. This is incorrect as the SAE J357 OCT 99 Information Report Physical and Chemical Properties of Engine Oils provides this definition "***A lubricant additive agent is a material designed to enhance the performance properties of the base stock or to improve the base stock properties that do not naturally exist with the base stock***." Clearly, ^{Z}Max does neither of these two functions, as it is not designed to improve or enhance any qualities of the engine oil. Introducing it into the engine oil is merely the means to transport ^{Z}Max directly to the engine's metallurgy.

The following provides a compilation of essentially all testing programs supporting those performance claims mentioned above. They are organized into nine sections with a summary for each section provided below. The detailed individual reports can be made available upon request.

Inactivity towards Additives - Since ^{Z}Max may be mistaken as being an additive, laboratory testing to show its non-reactivity when mixed with formulated engine oils would confirm ^{Z}Max does not interact/interfere with those additive ingredients in engine oils. The approach taken was to have selected laboratory tests conducted back-to-back first on a fully formulated SAE 5W-30 SJ engine oil without the ^{Z}Max followed those same tests on a blend of that oil containing 10% by volume ^{Z}Max.

Any significant changes in test results would certainly demonstrate some reaction had occurred whereas no change would show ^{Z}Max to be "inert" towards the engine oil's additives.

The laboratory tests selected were those that would reveal any sensitivity to additive interactions or incompatibility. These first eight tests were: ASTM D664 (Total Acid Number), ASTM D2896 (Total Base Number), ASTM D4742 (Oxidation Stability of Gasoline Automotive Engine Oils by Thin-Film Oxygen Uptake), ASTM D130 (Copper Strip Corrosion), FTM Standard 791C Method 3470 (Homogeneity and Miscibility), General Motors 9099P (Engine Oil Filterability Test), ASTM D892 (Foaming Characteristics of Engine Oils), and ASTM D6082 (High Temperature Foaming Characteristics of Engine Oils). The remaining three tests dealt with viscosity and were selected to merely assess the degree of change since adding 10% ^{Z}Max would slightly lower the overall viscosity. These remaining tests were: ASTM D5133 (Low Temperature, Low Shear Rate, Viscosity/Temperature Dependence of Lubricating Oil Using a Temperature Scanning Technique), ASTM D445 (Kinematic Viscosity), and ASTM D5293 (Apparent Viscosity of Engine Oil Using the Cold Cranking Simulator).

The results of these first eight tests revealed ^{Z}Max **did not generate any significant changes that would have indicated any additive interaction or some additive/base stock incompatibility.** All of the changes shown were either within the precision limits for the individual tests or in some instances there was no change whatsoever. However, the results obtained from the Homogeneity and Miscibility (H&M) test warrant further comment. This test determines whether fully formulated engine oils are homogeneous and completely miscible with other engines oils they might encounter in service. The presence of ^{Z}Max in the SAE 5W-30 SJ engine oil when tested individually against each of the six reference oils required in the H&M test **did not result in any indication of incompatibity or additive interaction being evidenced**. The results of the remaining three tests (i.e., Gelation Index through the Cold Cranking Simulator) revealed minor changes reflecting the presence of the lighter (i.e., lower viscosity) ^{Z}Max component that was fully anticipated. In summary, the testing results revealed the absence of any additive interactions with ^{Z}Max. Should ^{Z}Max have reacted in any manner with the additive package or any of its individual ingredients, there would have been significant changes in the results of those tests that were conducted.

Metal Penetration - Arch Analytical Services (Cheshire, CT) utilized Auger Electron Spectroscopy (AES) to assess the ability of ^{Z}Max to penetrate metal surfaces. A testing protocol was developed and tests were subsequently conducted on cast iron and aluminum alloy specimens similar in composition to metals used in current model automotive engines. The metal specimens were immersed in the test fluids for seven to fourteen days under temperature-cycled conditions (i.e., ambient to 100 °C to simulate some modes of an operating engine environment). Comparative tests of ^{Z}Max by itself and in blends with a commercial SAE 5W-30 SJ engine oil showed the ^{Z}Max by itself and when blended with the engine oil, penetrated both types of metal **far deeper than engine oil alone**. Although it was not possible to precisely quantify the difference in penetration depths between the engine oil, and the engine oil with ^{Z}Max, measuring the percent Carbon (C) by AES revealed the presence of ^{Z}Max in the engine oil resulted in a **82% greater penetration (i.e.,** % C for engine oil alone was

27% versus % C for engine oil with ^{Z}Max was 49%). This ability to soak (i.e., be absorbed) into metal surfaces is the key to ^{Z}Max's effectiveness.

Carbon Reduction and Dispersion - A testing program conducted by Savant Inc. (Midland, MI) used ASTM D7097 (Determination of Moderately High Temperature Deposits by Thermo-Oxidation Engine Oil Simulation Test), commonly referred to as the TEOST MHT-4 test to assess carbon deposit formation. This procedure is routinely used for measuring the ability of fully formulated engine oils to control high temperature deposits and resist oxidation. This test, a requirement for meeting current SAE/API and ILSAC engine oil performance standards, basically simulates deposit formation in the piston ring belt area of a modem engine by allowing oil to flow over a heated steel tube in an oxidizing atmosphere. Blends of ^{Z}Max and two different reference engine oils were made. Again, the metal specimens were exposed to the same preconditioning cycle described above. The two reference engine oils differed in their ability for controlling carbon deposits, one being a high deposit oil while the other being a low deposit oil. The results of these tests revealed a **reduction in carbon deposits** when ^{Z}Max was present, with **reductions of 14.6%** and **12.3%** for the low and high deposit reference oils respectively. Multiple testing was performed to demonstrate these **obtained results were statistically significant** in affirming that ^{Z}Max does lower carbon deposits.

In an another laboratory study conducted by Oil-Chem Research Corporation (Bedford Park, IL), sludge from an engine oil pan was mixed with different fluids and heated to 100 °C with vertically hung strips of chromatography paper partially immersed in the sludge/fluid mixtures. Through capillary action, the fluids migrate up the paper. Depending upon the ability of the fluid to disperse the sludge components, the capillary action will transport different amounts and types of carbonaceous matter. Comparative testing of ^{Z}Max by itself and ^{Z}Max/oil blends versus engine oil, mineral oil, and several major aftermarket additives showed much larger amounts of carbon matter being transported when ^{Z}Max was present. This demonstrated the ability of ^{Z}Max to disperse engine deposits which was further confirmed in subsequent engine dynamometer testing as well as the ASTM D7097 data described above.

Friction and Wear Bench Tests - A series of ASTM bench tests which are used to assess the fundamental behavior of oils to control friction and wear between rubbing metal surfaces were conducted by Savant Inc. (Midland, MI). It should be noted that none of these tests are correlated to any engine dynamometer performance test. Six different test procedures which varied both in the mechanical configuration and applied loading were selected. Each procedure was slightly modified by the same preconditioning of metal specimens mentioned above. The following compares test results of a commercial SAE 5W-30 SJ engine oil without and with ^{Z}Max, the **reduction in wear** and **coefficient of friction,** or **increase in time to failure** being a direct result of ^{Z}Max.

Although multiple testing was performed, an insufficient number of tests were conducted to statistically validate the benefits of ^{Z}Max in reducing friction and wear. However, the Savant report stated "*..this study of the friction and wear characteristics of ^{Z}Max has indicated generally positive effects when applied to a modern SAE 5W-30 engine oil.*"

1. ASTM D4172 Four Ball Wear Test
   3 to 11% reduction in the wear scar diameter

2. ASTM D5183 Four Ball Wear and Coefficient of Friction Test
   9 to 61 % reduction in the wear scar diameter
   10 to 14% reduction in the coefficient of friction

3. ASTM G99 Pin-on-Disk Test
   Up to **2% reduction** in the coefficient of friction

4. Savant Progressive Load Test
   10 to 22% reduction in the coefficient of friction
   29% less weight loss of the pin

5. ASTM D2714 Block-on Ring Test
   4 to 13% reduction in the coefficient of friction
   3 1 % reduction in specimen weight loss
   16% reduction in wear scar diameter

6. ASTM D5620 Thin Film-on-Vee Block Test
   Up to 300% increase in time to failure

All of these tests showed some improvements in both friction (i.e., lowering the coefficient of friction) and reduced wear when ^{Z}Max was present. Further, there were no incidents that the presence of ^{Z}Max caused any adverse or negative effect in any of these tests.

Bench Rust Tests - Using the ASTM D1748 Rust Protection by Metal Preservatives in the Humidity Cabinet procedure, a series of aviation piston engine oils were evaluated by Phoenix Chemical Laboratory Inc. (Chicago, IL) for their ability to prevent the onset of rusting from moisture alone with and without ^{Z}Max. The procedure was modified by first incorporating the same preconditioning of metal specimens mentioned above. Using three commercial aviation piston engine oils, the time before the start of rusting was **increased** by **10 to 100 %** when ^{Z}Max was present in the oil. These results demonstrate the ability of ^{Z}Max to provide enhanced surface protection from atmospheric rusting.

SAE J1321 Fuel Economy Tests - Four separate tests on the effectiveness of ^{Z}Max to improve fuel economy were conducted using in-use vehicles tested in accordance to the SAE J1321 Joint TMC/SAE Fuel Consumption Test procedure. In summary, the test protocol requires measuring the fuel consumption (by weight to improve accuracy) of a group of test and control vehicles by driving the vehicles over a fixed-length road course or test track at a fixed rate of speed. The test is conducted in two phases, a baseline phase before any changes are made to the vehicles, and a test phase in which the test vehicles receive a change. The difference in fuel consumption between the baseline and test phases is used to calculate the change in fuel economy. In this case, the test vehicles received the ^{Z}Max treatment in the crankcase, transmission and fuel tank. The control vehicles remain constant between the baseline and test phases and are used in the calculations to correct for the influences of ambient weather conditions. A summary of the four tests follows.

1. Claude Travis Associates (Grand Rapids, MI) - This test was conducted on an on-road course with two 1994 Class 8 Trucks powered by Cummins N1 diesel engines. One vehicle received ^{Z}Max treatment in the fuel, crankcase and transmission while the other vehicle was unchanged between the base and test periods. The test results showed a **fuel economy improvement of 2.61%** for the test vehicle.

2. Automotive Testing & Development Services, Inc. (Ontario, CA) - This test was conducted with three test vehicles and two control vehicles at the Las Vegas Motor Speedway in June of 2000. A summary of the test results follows.

Vehicle	**% MPG Improvement**
1992 Plymouth Acclaim, 2.5L	6.4 to 7.7%
1999 Chevrolet Malibu, 3.1L	8.8 to 9.5%
1995 Ford F-150, 5.0L	~0.1%

3. Automotive Testing & Development Services, Inc. (Ontario, CA) - This test was conducted with seven test vehicles and one control vehicle at the Las Vegas Motor Speedway in May of 2001. A summary of the test results follows.

Vehicle	**% MPG Improvement**
1996 Kia Sephia	4.6
1996 Ford Escort Wagon	3.3
1996 Ford Taurus	6.6
1989 Ford Crown Victoria	3.6
1995 Ford F-150 P/U	0.2
1997 Chevrolet Lumina	4.7
1995 Chevrolet Astro Van	2.5
Average % Improvement -	**3.6**

4. Gerald H. Keller, Consultant (Palos Heights, IL) - This test was conducted with eight test vehicles and one control vehicle at the Chicago Motor Speedway in June of 2001. A summary of test results follows.

Vehicle	**% MPG Improvement**
1991 Mazda, 2.2L	12.7
1988 Toyota Corolla, 1.6L	2.4
1986 Chrysler LeBaron, 2.2L	14.9
1994 Oldsmobile Cutlass, 3.4L	2.8
1991 Mercury Cougar, 3.8L	2.6
1989 Toyota Camry, 2.0L	4.8
1985 Dodge Van, 225 CID	0.9
1990 Chevrolet Beretta; 3.1L	3.1
Average % Improvement -	**5.5**

These test results show a wide range in the change of fuel economy due to ^{Z}Max. Since all of these vehicles had seen a relatively high level of road use (odometers ranged from 43 to 226,000 miles), the engines had accumulated carbon in the critical sealing areas. Thus, the ability of ^{Z}Max to penetrate the metal surfaces and improve engine sealing resulted in improved engine efficiency.

A statistical analysis of the data generated from the SAE J3121 fuel economy tests conducted by Automotive Testing & Development Services, Inc in June 2000 and May 2001, and the Chicago test conducted by Gerald Keller in June 2001 was performed. The method used in this analysis involved the "***Dependent Samples t-Test***" methodology and is widely used where the significance of an observed change in two populations of data is to be measured. Applying this methodology, each of the three series of SAE J3121 fuel economy tests mentioned above conducted on ^{Z}Max **afforded statistically valid improvements in fuel economy resulting from the presence of ^{Z}Max.**

Vehicle Emissions Tests - Two vehicular emission test programs have conducted with ^{Z}Max and are described below.

1. Automotive Testing & Development Services, Inc. (Ontario, CA) - This test program employed five vehicles that were obtained from a rental agency. The vehicles were a 1996 Ford Escort, 1989 Ford Crown Victoria, 1995 Ford F-150 P/U, 1997 Chevrolet Lumina, and a 1995 Chevrolet Astro Van. After inspection and lubricant changes, the vehicles were base-lined for their emissions levels using the FTP 40 CFR-86 procedure. After a second lubricant change, the vehicles were treated with ^{Z}Max and the emissions tests were repeated. At this point the vehicles were returned to the rental agency and allowed to accumulate mileage for a thirty-day period at which point the vehicles were emissions tested again. This cycle was repeated for an additional thirty-day period affording sixty days of road use. The average results of these emissions tests are summarized in the following table.

	% Reduction		
	HC	CO	NOx
After 30 days of road use	**-9.7%**	**-15.3%**	**-9.7%**
After 60 days of road use	**-4.8%**	**-4.8%**	**-8.3%**

The **reductions in all three pollutants** is a significant event and is attributed to the action of the ^{Z}Max in cleaning carbon from the engine's critical sealing areas and parts of the emission control system such as the oxygen sensor.

2. Gerald H. Keller, Consultant (Palos Heights, IL) - These tests were conducted on the same vehicles as used in the SAE J1321 fuel economy tests (June 2001) using the BAR 90 procedure. This is the procedure recommended by EPA for state emission surveillance purposes. The eight test vehicles were tested for their emissions at the start and end of the fuel economy testing which represented about 1,500 miles accumulated after adding ^{Z}Max. The average change in HC and CO levels are shown below. The NOx data is not considered since the BAR 90 procedure does not apply load to the vehicle, and thus NOx data has little significance for on-road emissions levels.

	% Reduction
HC emissions @ idle	**-42.2%**

HC emissions @ 2500 rpm	**-76.0%**
CO emissions @ idle	**-52.9%**
CO emissions @ 2500 rpm	**-52.2%**

Engine Dynamometer Testing -A variety of different stationary engine dynamometer tests have been conducted on ^{Z}Max providing information on fuel economy, power, wear, blow-by, and deposits. These tests are summarized below.

1. CLR Engine Testing - The CLR engine is a single cylinder carbureted engine which develops peak power output of 16.5 hp @ 3000 rpm. This engine has been used for many years in petroleum product research and development activities to assess the influence of new product formulations on engine performance. The engine is currently used by the petroleum industry for qualification to SAE/API/ILSAC engine oil standards. Although this single cylinder engine is used primarily for measuring bearing weight loss and shear stability of multigraded oils, it nonetheless is an excellent laboratory engine capable of providing additional engine performance measurements (e.g., fuel consumption, horsepower, etc.) as evidenced by the large number of technical papers in the literature citing the use of this engine.

Ten (10) different evaluations of ^{Z}Max have been conducted with this engine. Each evaluation consisted of two tests, a baseline test on an engine oil without ^{Z}Max followed by a second test where the same oil and fuel were treated with ^{Z}Max. The tests used a modification of standard industry protocols, the L-38 (ASTM D5119) and the Sequence VIII (ASTM D6709). The major modification was to introduce an engine-preconditioning phase in the procedure for initially allowing ^{Z}Max to be absorbed. This modification, a ten hour preconditioning period, was used on both the baseline and ^{Z}Max tests to insure both tests were being conducted identically. The results of these tests, which were conducted by Auto Research Labs, Inc. (Chicago, IL) and later by the Oil-Chem Research Corporation (Bedford Park, IL), are as follows.

a. SAE 50 Aircraft Piston Engine Oil + 5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel (modified L-38 test procedure)

8.3% increase in power
8.5% improvement in fuel efficiency (bsfc)
17.0% reduction in blow-by
Piston skirt **wear reduced** from **9.5% to 3.5%**
Intake valve stem **wear reduced** from **18% to7%**
Exhaust valve stem **wear reduced** from **3% to 1%**
Intake valve **deposits reduced** from **5% to 2%**
Exhaust valve **deposits reduced** from **3% to 1%**

b. Pennzoil SAE 10W-30 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel (modified Sequence VIII test procedure)

7.6% increase in power
6.6% improvement in fuel efficiency (bsfc)
4.3% reduction in blow-by

69% reduction in exhaust valve guide wear
Used oil **wear metals reduced** by **over 50%**

c. MotorCraft SAE 5W-20 SJ + 5.0% ^{Z}Max and 12 oz. ^{Z}Max in the fuel (modified Sequence VIII test procedure)

3.8% increase in power
2.8% improvement in fuel efficiency (bsfc)
69% reduction in exhaust valve guide wear
Increase in second ring gap reduced from 0.0002 to 0.0001 inches
Used oil **wear metals reduced** by **over 50%**

d. MotorCraft SAE 5W-20 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel (modified Sequence VIII test procedure)

5.2% increase in power
4.2% improvement in fuel efficiency (bsfc)
3.5% reduction in blow-by
57% reduction in exhaust valve guide wear
Increase in top ring gap reduced from 0.0001 to 0.0 in.
Used oil **wear metals reduced** by **over 50%**
Less deposits on piston lands, grooves and skirts

e. MotorCraft SAE 5W-20 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel (modified Sequence VIII procedure). In this test, the baseline phase was run as usual. Then, instead of reassembling the engine with new parts and engine cleaning as was done in the previous four tests, the engine was measured and reassembled with the used parts from the baseline phase.

7.0% increase in power
6.6% improvement in fuel efficiency (bsfc)
0.2% reduction in blow-by
92% reduction in exhaust valve guide wear
Used oil **wear metals reduced** by **over 50%**

A statistical analysis of the data generated from the CLR/Sequence VIII engine testing conducted on the above four tests (i.e., numbers 1b through 1e) was performed to assess the individual hourly horsepower and fuel efficiency readings. The method used in this analysis involved the "***Dependent Samples t-Test***" methodology and is widely used where the significance of an observed change in two populations of data is to be measured. Applying this methodology on each of the four engine tests run on ^{Z}Max at different concentrations and with different oils has shown the **changes in horsepower (bhp) and fuel efficiency (bsfc) were statistically different at a 99% confidence level**. This analysis provided evidence that the o**bserved improvements in these parameters were real and not simply due to test variability**.

f. Mobil 1 SAE 10W-30 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel (modified Sequence VIII test procedure)
7.2% increase in power

6.6% improvement in fuel efficiency (bsfc)
17.4% reduction in blow-by
10.8% reduction in bearing weight loss
18.1% reduction in ring weight loss

g. Mobil 1 SAE 10W-30 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel **(**modified Sequence VIII test procedure) repeat of the above test to demonstrate repeatability of method.

6.5% increase in power
5.8% improvement in fuel efficiency (bsfc)
30.1% reduction in blow-by
25.3% reduction in bearing weight loss
52.1% reduction in ring weight loss

h. Amsoil SAE 10W-30 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel **(**modified Sequence VIII test procedure).

2.5% increase in power
2.4% improvement in fuel efficiency (bsfc)
12.1% reduction in blow-by
94% reduction in valve guide bore wear
37.3% reduction in bearing weight loss
12.1% reduction in ring weight loss

i. Pennzoil SAE 5W-30 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel **(**modified Sequence VIII test procedure).

4.4% increase in power
4.3% improvement in fuel efficiency (bsfc)
7.5% reduction in blow-by
16.7% reduction in bearing weight loss
58.0% reduction in ring weight loss
97% reduction in valve guide bore wear

j. Pennzoil SAE 5W-30 SJ + 8.5% ^{Z}Max and 12 oz. ^{Z}Max in the fuel **(**modified Sequence VIII test procedure) repeat of the above test conducted approximately one year later.

4.1% increase in power
3.9% improvement in fuel efficiency (bsfc)
3.8% reduction in blow-by
32.7% reduction in bearing weight loss

2. Ford 2.0L Engine test - For this test, a new (1,000 miles) Ford 2.0L engine from a 2000 Ford Escort was mounted on an engine dynamometer testing stand at Oil-Chem Research Corporation, fully equipped for engine parameter control and continuous data monitoring. The test procedure consisted of running the engine at conditions which simulated 65 mph (2500 rpm and 26.0 hp load). The fuel rate was allowed to float to what ever level the engine's power control module would dictate. The engine was first base-lined on Pennzoil SAE 5W-30 SJ oil for 14 hours with the power output controlled to 26.0 hp. Without changing the oil, the crankcase and fuel were treated with 12 oz. of ^{Z}Max.

The engine was then run for a preconditioning phase consisting of one hour run periods followed by 5 to 12 hours soak periods. After ten run/soak cycles, the engine was again run for 14 hours at the same conditions as the baseline phase. The difference in fuel efficiency resulted in a **2.3% improvement** due to ^{Z}Max. However, additional testing was not able to be conducted to statistically validate the observed improvements.

3. Shaw Dynamometer Engine Services - This test was conducted on an engine dynamometer test stand using a Chevrolet 468 CID engine. The engine was first base-lined for high output conditions through a controlled acceleration ramp while monitoring torque and horsepower. ^{Z}Max was added to the crankcase at a treat rate of 7.5% and 2.0 oz. was poured into the carburetor. The **measured power** of the engine **increased** by **1.1 to 4.2 %** (depending upon the engine rpm) after the ^{Z}Max treatment. However, additional testing was not able to be conducted to statistically validate the observed improvements.

4. Yamaha 600 Legend Test- A 1200cc Yamaha engine was mounted on an engine test stand at Oil-Chem Research Corporation. Horsepower and torque were measured at speeds from 6,000 to 10,000 rpm in 1,000-rpm increments. After obtaining baseline data, ^{Z}Max was added through the carburetion system and the engine run for a short period followed by a four-day soaking period. The engine was run again through the rpm range. The average **increase in horsepower and torque** after the ^{Z}Max treatment was **6.4%** and **6.3%** respectively. However, additional testing was not able to be conducted to statistically validate the observed improvements.

5. Labeco Equipment Corporation - A single cylinder 17.6 CID engine (the predecessor to the CLR engine discussed earlier) was run at two test conditions, 2,700 rpm and either 50" or 75" boost in inlet air pressure. Oil and water temperatures were controlled to 195 and 270 °F respectively. All other engine settings were for best power output. The ^{Z}Max was added to the crankcase at a treat level of 5% and 1% was put in the fuel. The indicated horsepower **increased by 2.8 to 6. 1 %**, while the fuel consumption **decreased by 3.8 to 8.2%** after ^{Z}Max treatment. However, additional testing was not able to be conducted to statistically validate the observed improvements.

6. Armour Research Institute - This test was run a 6-cylinder Chevrolet engine using the L-4 procedure for oil oxidation. The test oil, a SAE 50 aviation piston engine oil, was first evaluated for its viscosity characteristics after the 36-hour test. The test was repeated with the same oil but containing 5% ^{Z}Max. At the end of the test, the viscosity of the untreated oil increased by 89% while the viscosity of the oil with ^{Z}Max increased by **only 16%.** However, additional testing was not able to be conducted to statistically validate the observed improvements.

7. Cummins Michigan. Inc. - This test facility has the capability to test a full size truck on a vehicle dynamometer and measure power output at highway speeds. The test vehicle from the Claude Travis Associates SAE J1321 fuel economy test discussed earlier was base-lined at this facility before the ^{Z}Max treatment, and then tested again after 7000 miles of road use. The truck was developing **~7% more**

horsepower during this second test, which showed ^{Z}Max had restored power in the engine. However, additional testing was not able to be conducted to statistically validate the observed improvements.

Controlled Field Tests - Two controlled field evaluations of ^{Z}Max have been conducted and are summarized below.

1. Executive Helicopter Inc. (Chicago, IL) - This company had a fleet of helicopters which were powered by Lycoming HIO 360 CIA engines and operated out of Chicago Midway Airport. One of these units received regular treatments of AvBlend (the same formulation as ^{Z}Max with a different trade name) and the engine received overhauls at 1,000 hours of operation by Blueprint Aircraft Engines, Inc. The normal routine for engine overhaul at 1,000 hours is to oversize and/or re-chrome piston cylinder walls to restore the proper dimensions. During the use of AvBlend, it was observed that cylinder wear (bore size, out-of-roundness, choke) was essentially still at new factory specifications, and the exhaust valves and guides were free of deposits, and also had minimal wear (.001 inch increase in valve/guide clearance). Because of these findings, the FAA approved the extension of time between overhauls in several increments up to 1,500 hours while the AvBlend was being used. The cylinders from this engine were continuously monitored until they were retired after 7,800 hours of use. Normally, cylinders can only achieve one overhaul cycle before they need oversizing and/or re-chroming. Based on this field demonstration, the FAA granted approval for the use of AvBlend as a supplement to the crankcase oil. This is the only product of its kind which has received such an approval.

2. Scheibert Energy Company (Honolulu, HI) - This company is in the business of power generation on the island of Oahu. Part of the plant equipment uses Hercules 8.8L V-6 propane fired engines in a cogeneration station. ^{Z}Max was added to oil, a Shell Rotella SAE 40, at a concentration of ~3%. After the addition of ^{Z}Max, the engine efficiency **increased by 17.3**%. Also, exhaust temperature was **reduced by 120 °F**. These changes were observed during the entire 5,000-hour service period.