



The First in Synthetics®

FIELD STUDY

Refuse Hauler Fleet

AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil delivers maximum performance, protection and cost savings for Nordic Waste's fleet of refuse haulers.



- *Fewer Oil Changes*
- *Reduced Downtime*
- *Less Waste Oil*
- *Reduced Maintenance Costs*
- *Extended Equipment Life*





In order to test the performance capabilities of AMSOIL 15W-40 Synthetic Heavy Duty Diesel and Marine Motor Oil (AME), AMSOIL sought a partner with a fleet that operated in truly severe conditions. The perfect match was found in Duluth, Minn.-based Nordic Waste. Nordic Waste operates a fleet of 10 International refuse haulers, providing trash and recycling pickup to residential and commercial customers in the greater Duluth/Superior, Wis.

region. Nordic's trucks operate in the bitter cold of sub-zero winters as well as on humid summer days that can top out at over 90°F. In addition, Lake Superior's influence on the area's weather patterns can create extreme temperature swings just miles from the lake, something Nordic's trucks encounter regularly. The company's fleet runs 12 hours a day with frequent stops and red-lined starts, all while hauling up to 22,000 lbs. of refuse and navigating the seriously steep hills of Duluth.

As if the geographic challenges aren't enough, perhaps the greatest strain these refuse haulers' engines face is dumping the refuse. This action requires the engine to remain near or above redline throughout the process and shakes the truck enough to nearly lift the front tires off the ground. Nordic's trucks dump their contents twice daily, challenging the oil's shear stability on a regular basis.

Navistar DT466

Nordic Waste was chosen to participate in this study not only because refuse haulers in general provide a severe operating environment for oil, but also because of the particular engine in the company's 2006 International 7400 rear-loading truck. Notoriously hard on oil, the Navistar DT466 diesel engine is a 7.6L inline six-cylinder designed specifically for use in large, commercial International trucks. Nordic Waste initially installed Shell Rotella T 15W-40 (239 hours), and the oil was monitored through oil analysis for the duration of the drain interval. For the subsequent drain interval, Nordic installed AMSOIL 15W-40 Synthetic Heavy Duty Diesel and Marine Motor Oil and monitored the oil's performance via oil analysis. Both oils' shear strength and TBN retention ability were examined using ASTM

testing procedures. The subject truck maintained its usual operating procedure throughout the test period, and the same driver operated the truck on the same route the entire time. AMSOIL used the oil analysis results from the initial drain interval, the subsequent drain interval and a thorough teardown and inspection by an independent, certified International mechanic to evaluate the performance of AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil.



HEUI

The Navistar DT466 engine employs a hydraulically actuated, electronically controlled unit injector (HEUI) system that uses engine oil pressure to run the fuel injectors. The HEUI system was designed to produce lower combustion noise and reduce hydrocarbon and nitrous oxide levels during combustion, offering quieter, cleaner diesel engine operation. HEUI systems feature a variable pump (in addition to the oil pump) that pressurizes the oil according to the fuel injection system's needs, placing a considerable amount of additional strain on engine oil. HEUI systems can raise oil pressure to as high as 3,500 psi, creating great potential for shearing and adding significant stress to motor oil that is already operating in a severe environment. The HEUI system's reputation for shearing less robust motor oils made the DT466 engine the perfect choice for testing the durability of AMSOIL Synthetic Heavy Duty Diesel and Marine Motor Oil.



983-HOUR DRAIN INTERVAL

Used Oil Analysis

Wear metal levels were tracked through oil analysis for the duration of the drain interval. As the results reveal, the AMSOIL diesel oil contained wear metals well below International's published condemnation limits, even after more than 900 hours of use.

Figure 1 displays the accumulation of copper wear particles in AMSOIL Synthetic Diesel and Marine Motor Oil over 983 hours. Due to the extreme environment created by the HEUI system, the condemning limit for copper levels in the DT466 engine is 60 parts per million (ppm). The HEUI system's tendency to cause oil shearing thins out lesser oils at normal operating temperatures and increases the likelihood for abnormal engine wear. As the results demonstrate, AMSOIL 15W-40 Synthetic Diesel Oil provided outstanding shear stability for the duration of the 983-hour drain interval.

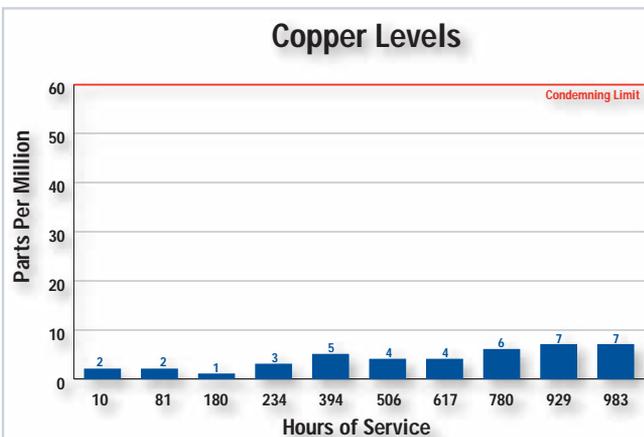


Figure 1

Figure 2 charts the rate at which iron wear particles developed. Once again, the extraordinary demand the engine's HEUI system places on engine oil results in a low condemnation limit of 200 ppm of iron. Even after 983 hours of use, AMSOIL Synthetic Diesel and Marine Motor Oil contained less than 100 ppm of iron.

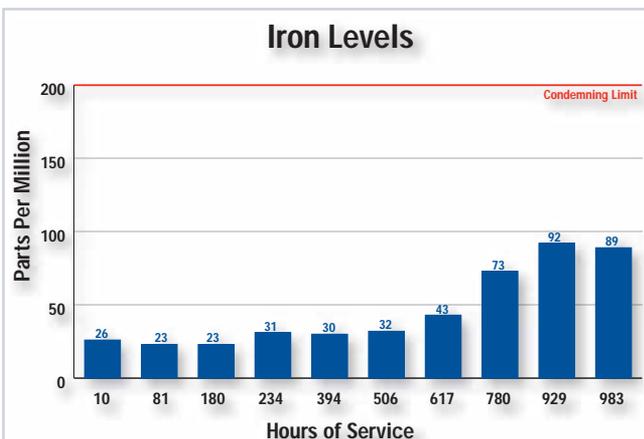


Figure 2

Figure 3 details the accumulation of lead particles over the drain interval. The condemnation limit for lead content is 60 ppm. A sudden spike in lead levels or levels that approach the condemning limit indicate an abnormal wear situation and can indicate the need to drain the oil. AMSOIL Synthetic Diesel and Marine Motor Oil maintained consistently low lead levels throughout the 983-hour drain interval.

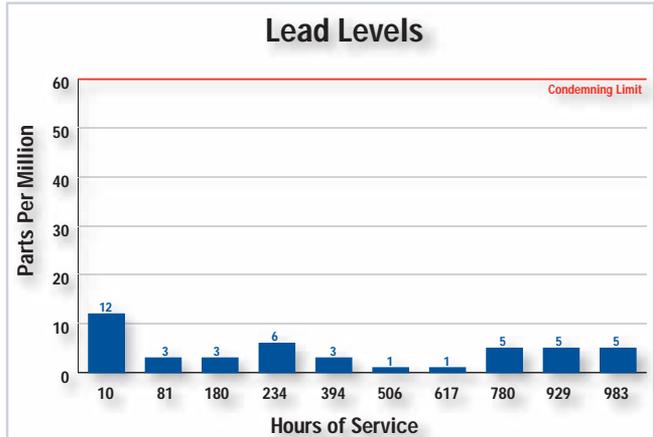


Figure 3

Maximum Durability

AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil maintained exceptional lubrication properties for the duration of the 983-hour drain interval. It maintained viscosity better than Shell Rotella T did, measuring 12.33 centistokes (cSt) when drained. Shell Rotella T, on the other hand, measured 10.17 cSt after its 239-hour oil drain interval. AMSOIL Diesel Oil demonstrated superior shear stability over an extended drain interval, even in severe service.

Figure 4 shows kinematic viscosity of Shell Rotella T and AMSOIL Synthetic Diesel and Marine Motor Oil for the duration of their respective drain intervals. The trend line for a high-quality motor oil should remain relatively flat for the entire service period. AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil shows a stable trend over the extended service period, well beyond the OEM-recommended drain interval.

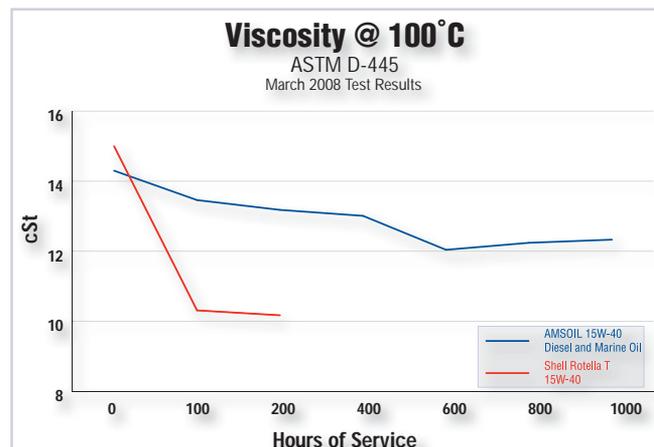


Figure 4

Superior Corrosion Protection

An oil's ability to maintain corrosion protection throughout its service life is measured by Total Base Number (TBN). AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil is formulated with a high 12 TBN to ensure corrosion protection from combustion blow-by and exhaust gas recirculation (EGR) for the life of the oil. The oil displayed excellent TBN retention ability for the entire 983-hour drain interval.

Figure 5 shows TBN results for AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil and Shell Rotella T for the duration of their respective drain intervals. TBN levels and hours of service have an inverse relationship; as hours increase, TBN decreases. It is important that the slope of the TBN trend line is gradual and spans the life of the lubricant. A sharp downward trend indicates diminished protection, which, if not addressed, can result in piston deposits and ring sticking. The performance of AMSOIL in the TBN test is in line with how a high-quality oil should perform. It maintains TBN levels to effectively neutralize acidic by-products of combustion and keep engine components free of deposits and corrosion.

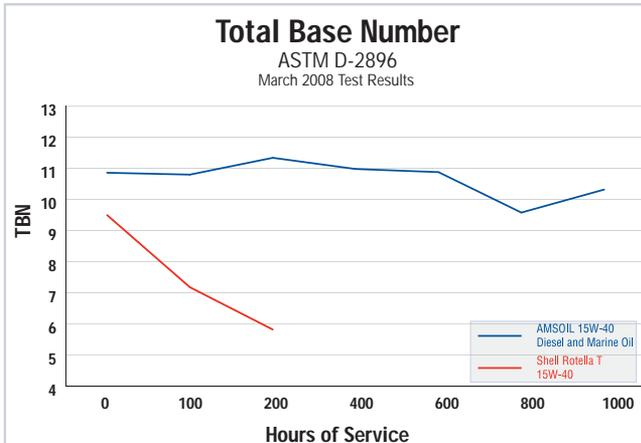


Figure 5

ROUTINE ENGINE TEARDOWN

At approximately 8,000 hours of use, Nordic Waste brought its International 7400 refuse hauler to certified International Truck mechanic Dan Lee for a routine teardown. Lee, who specializes in the DT466 engine, examined the pistons, rings, wrist pins and bearings, while the top and bottom cylinder (bore) diameters were measured by PDQ Engine and Machine in Duluth, Minn.

Deposit-Free

Figure 6 shows the subject truck's valvetrain. The valvetrain is typically prone to varnish and sludge deposits on non-moving parts and valve springs. Sludge and varnish buildup appears as a thick, dark residue. Many times, sludge is baked into a hard-to-remove carbonaceous consistency associated with an engine lubricant being overloaded with insolubles. AMSOIL Synthetic Diesel and Marine Motor Oil's robust additive package and high TBN kept the DT466 cylinder head and valvetrain free of deposits and sludge.



Figure 6

Reduced Wear

Figure 7 shows one of the cylinder liners from the DT466 in Nordic's truck. Lubrication is essential for the bore to remain operational. If sufficient lubrication is not provided, excess heat may cause thermal expansion, which can force the cylinder out of round and significantly increase the potential for wear. After nearly 8,000 hours of operation, the OEM cross-hatch pattern in the cylinder is still evident, demonstrating the oil's excellent wear control in spite of the extreme shaking, jarring and revving the motor is subjected to on a daily basis. Though it is slight, the most wear occurred at the top dead center of piston movement, where there is only light oil film lubrication. **Figure 8** shows top and bottom bore measurements along with the OEM specifications. Measurements for the sixth cylinder were unavailable as International Truck retained that sample for their records.

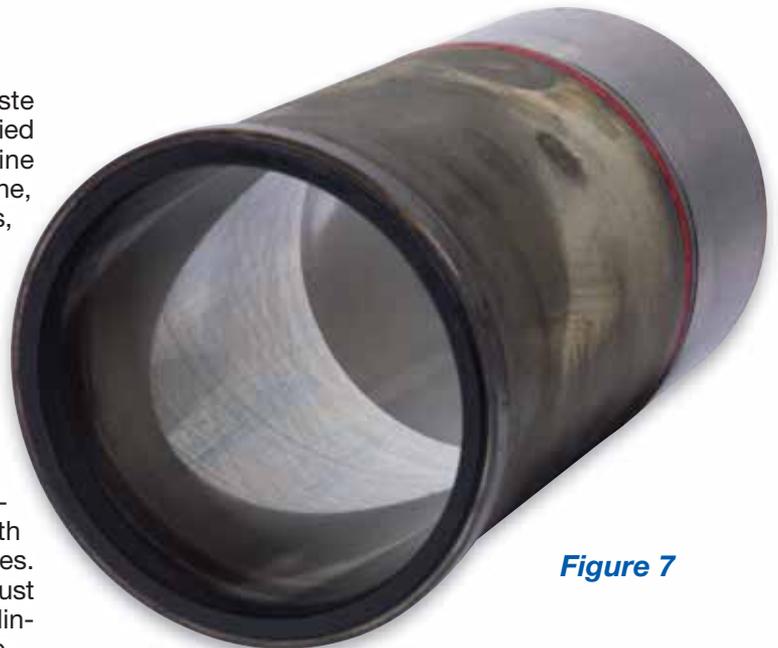


Figure 7

Piston cleanliness in this engine was representative of an engine that had accumulated far fewer hours. In fact, Lee indicated that each piston was suitable for continued use. AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil resisted oxidation and volatility to allow minimal carbon deposit development between compression rings, on the crown and inside the ring land area. Conventional lubricants can allow undesired carbon buildup in these areas, which can cause piston ring sticking and unnecessary wear. After nearly 8,000 hours of service, the piston rings and skirts in Nordic's truck measured within OEM specifications for a new DT466 engine.

Figure 8 shows the top and intermediate piston ring measurements. Piston rings are measured by determining the gap in each ring. As piston rings experience wear, additional room for ring expansion is created, widening the ring gap. Lower measurements equate to less wear, yet any measurement within OEM specifications is equivalent to rings when new. All of the top piston rings were still within International specification limits for new engines, with an average measurement of 0.015 inches. All of the intermediate rings but one measured 0.074 inches, which is within International specifications. Since all of the other rings had identical measurements, it is possible that the ring that was out of specified limits had been so since it was installed. **Figure 9** shows ring locations.

Figure 10 shows Lee measuring a piston skirt in order to determine the amount of wear that had



Figure 9



Figure 10

occurred. Skirt measurements are determined by measuring the outer diameter of the piston, halfway between the crown (top) and base. The diameters of each piston skirt from Nordic's truck were identical, measuring 4.585 inches (see **Figure 8**). The piston skirts showed no measurable wear and were within International specifications for a new DT466 engine.

Figure 11 shows an example of the piston skirt and crown from Nordic's DT466. Lee indicated that piston cleanliness was similar to engines that had accumulated significantly less hours and were suitable for continued use. None of the pistons showed any signs of abnormal or visual wear.



Figure 11

| | Top Bore | Bottom Bore | Top Ring | Intermediate Ring | Piston Skirt | Wrist Pin |
|------------|----------------|----------------|----------------|-------------------|----------------|------------------|
| OEM Spec | 4.590 - 4.591" | 4.590 - 4.591" | 0.014 - 0.026" | 0.065 - 0.075" | 4.584 - 4.586" | 1.8249 - 1.8251" |
| Part Set A | 4.5915" | 4.5905" | 0.016" | 0.074" | 4.585" | 1.826" |
| Part Set B | 4.5905" | 4.590" | 0.015" | 0.074" | 4.585" | 1.825" |
| Part Set C | 4.591" | 4.590" | 0.018" | 0.082" | 4.585" | 1.825" |
| Part Set D | 4.591" | 4.590" | 0.015" | 0.074" | 4.585" | 1.825" |
| Part Set E | 4.591" | 4.5905" | 0.014" | 0.074" | 4.585" | 1.825" |

Figure 8

Figure 12 shows one of the wrist pins from Nordic's truck. Extreme force in the combustion chamber transfers the load directly to the wrist pin, creating the need for a durable, shear-stable oil in order to prohibit metal-to-metal contact. The wrist pins from the Nordic Waste truck measured within OEM specifications. No flat-spotting occurred and, even after daily severe service over extended drain intervals, the wrist pins' measurements were similar to when originally pressed into the piston by the engine manufacturer. (See **Figure 8** for measurements.) Higher measurements equate to less wear because as wear occurs, wrist pin diameters are reduced. AMSOIL Synthetic Diesel and Marine Motor Oil's superior film strength delivered exceptional protection in this severe environment, effectively preventing component wear.

Figure 13 shows the bearings from Nordic's DT466 engine. No copper lining or discoloration was evident on the bearings, proving that very little wear occurred. They were very clean and showed insignificant levels of pitting in the bearing surface. According to Lee, each bearing was in good condition and showed wear levels consistent with those of a light-duty engine receiving four times as many oil changes.

"The lack of copper showing on the bearings proves minimal wear has occurred," said Lee. "For the hours on this unit, these bearings look very good. If it weren't for the routine maintenance interval requiring replacement, these bearings are still in good enough condition to be reused." Lee attributed the minor wear on the bearings to break-in wear when the engine was new. "What little wear was evident on the bearings was from engine break-in and the bearings look far better than many I have seen," said Lee. Engine bearings cannot be measured without the piston rods and end caps, which were put back into the engine prior to Lee's inspection.



Figure 12

USE OF AMSOIL SYNTHETIC DIESEL OIL SAVES MONEY

Nordic's Experience With Conventional Oils

Between the unique climate and geographic challenges, the HEUI system, constant use of the truck's hydraulic applications and regular near-redline operation, Nordic Waste's trucks provide a serious challenge for any motor oil. In fact, it was Nordic's search for an oil that could withstand the punishment doled out by its vehicles every day that led the company to AMSOIL.

"With the big hills, high heat and extreme cold we work in, nothing has performed better," said Nordic Waste Owner Brian Johnson. Johnson noted that Nordic Waste had installed other diesel oils in its trucks but none were able to provide the level of protection offered by AMSOIL. Prior to discovering AMSOIL, the conventional lubricants Nordic used would shear out of viscosity-grade rapidly and need to be changed at approximately 200 hours of service. Upon switching to AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil, Nordic Waste increased the average drain interval for its trucks from approximately 200 hours to nearly 1,000 hours.

Extreme-Temperature Performance

The extreme temperatures faced in the Duluth/Superior region place great strain on Nordic's fleet. Winter temperatures dropping below -30°F are not unusual, so cold starts and hydraulic functions are especially sensitive areas for Nordic Waste.

"Cold starts were a primary concern for us," said Johnson. "Even though we use block heaters in the winter, you never know when you might come to work and find that the breaker tripped or a driver forgot to plug in the truck the previous evening." Nordic's drivers begin their day around 3:30 a.m., so there is no time for troubleshooting or engine repairs prior to beginning their routes. The cold-start issues plagued Nordic Waste for nearly six months out of every year, until the company switched to AMSOIL products.



Figure 13

“With conventional lubricants, when trucks weren’t plugged in, starting would be difficult, if even possible, and even if the trucks turned over, engine protection would be minimal because no oil pressure would appear on the gauge,” said Johnson. The test truck’s operator, Wayne Carlson, noticed the difference with AMSOIL Synthetic Diesel and Marine Motor Oil right away. “The truck has excellent performance in winter,” said Carlson. “It fires right up without being plugged in and there is instant oil pressure with AMSOIL. In trucks I have driven using conventional lubricants, it could take more than a minute to build any oil pressure when cold, providing little engine protection.” AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil is formulated to provide exceptional cold-temperature performance. Its cold-flow properties have saved Nordic Waste time and money, and delivered peace of mind with the knowledge that the company’s trucks will start on even the coldest winter morning.

AMSOIL Diesel Oil Saves Money

Use of AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil, along with oil analysis, has allowed Nordic Waste to extend its trucks’ oil drain intervals to nearly 1,000 hours – four times the length of service possible when using Shell Rotella T. Nordic’s trucks are well-protected, so they stay out of the shop and on the road.

“We experience less downtime and have seen reductions in costs associated with engine overhauls and replacement parts,” said Johnson. Refuse haulers are very expensive, so maintaining spare trucks is not affordable for a small company. Operating with a minimal number of trucks requires maximum uptime to ensure customers are serviced properly. By delivering superior protection over extended drain intervals and improving engine reliability, AMSOIL Synthetic Diesel and Marine Motor Oil provides Nordic Waste consistent dependability and reduced maintenance (increased uptime). Increased uptime has helped Nordic Waste maintain an accurate schedule and provide excellent customer service – trucks are more readily available for routes when they aren’t in the shop for service. In addition to improving the company’s operations, extended drain intervals save Nordic a considerable amount of money annually.

“We buy significantly less oil, fewer filters and we experience lower labor costs,” said Johnson. “Our biggest savings have been the reduced number of engine overhauls and replacement parts.”

Use of AMSOIL 15W-40 Synthetic Diesel and Marine

Motor Oil saves Nordic Waste thousands of dollars in oil alone, in addition to reduced expenses for labor, filters and waste oil and used filter disposal. **Figure 14** shows the annual savings realized by converting one truck to AMSOIL Synthetic Diesel and Marine Motor Oil. The oil is installed in all 10 of Nordic Waste’s trucks, providing an annual savings of \$4,226.20* in oil costs alone.

Environmental Benefits

Use of AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil helps Nordic Waste reduce its environmental impact, something that’s important to a company that provides recycling services. Nordic’s extended drain intervals have reduced the amount of oil the company disposes of by up to 75 percent. In addition, AMSOIL Synthetic Diesel and Marine Motor Oil’s superior thermal resistance helps it effectively resist volatilization (burn-off) better than conventional oils. “This truck hardly ever consumes any oil; less than one quart per oil change, which is very good compared to oils in other trucks I have driven,” said Carlson.

Conclusion

AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil provides superior performance in the harsh environment faced by refuse haulers. Through oil analysis, Nordic Waste has been able to safely extend the oil drain intervals in the company’s fleet to more than four times the drain interval possible using Shell Rotella T. In this field study, AMSOIL Synthetic Diesel and Marine Motor Oil demonstrated excellent wear protection for the entire 983-hour drain interval. Its TBN retention was excellent, it provided exceptional corrosion protection and minimized sludge formation, as evidenced by the absence of corrosive areas or sludge buildup on engine components during the routine teardown. AMSOIL Synthetic Diesel and Marine Motor Oil prevented soot-thickening, resisted oxidation and minimized wear. It also maintained proper viscosity for the duration of the 983-hour drain interval in spite of the severe operating environment and HEUI injection system. Adversely, Shell Rotella T 15W-40 sheared out of viscosity-grade rapidly, requiring an oil change after only 239 hours of service. Nordic Waste’s use of AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil has improved the fleet’s performance and longevity, and reduced the company’s maintenance costs. AMSOIL saves Nordic Waste a significant amount of money annually.

| Money Saved by Using AMSOIL* | | |
|-------------------------------------|------------------------|--|
| | Shell Rotella T | AMSOIL 15W-40 Synthetic Diesel and Marine Motor Oil |
| Annual Hours | 2,500 | 2,500 |
| Oil Drain Interval (Hours) | 250 | 900 |
| Oil Changes Per Year | 10 | 3 |
| Cost Per Gallon | \$16.45 | \$36.05 |
| Cost Per Oil Change (7.5 Gal.) | \$123.38 | \$270.38 |
| Annual Cost Per Truck | \$1,233.75 | \$811.13 |
| Annual Savings | | \$422.62 Per Truck |

*November 2011 suggested retail pricing.
AMSOIL accounts buy at wholesale pricing, saving even more.

Figure 14

"In the two years I've been riding with AMSOIL, I've never experienced a single engine problem."

**– Wayne Carlson
Operator, Nordic Waste**

"With AMSOIL, we buy less oil, fewer filters, experience lower labor costs and save on engine overhauls and replacement parts."

**– Brian Johnson
Owner, Nordic Waste**

AMSOIL products and Dealership information are available from your local AMSOIL Dealer.

BRIAN DOBBEN

Former Sr OEM Engineer, Certified Lubrication Specialist

DMT Technical – Engineering Services

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