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PERFORMANCE OF ENVIROFUELS DFC AND LTP ON EMD 20-645E3

PUBLIC VERSION

Global Dredging Company

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EXECUTIVE SUMMARY

This report describes the results of a side-by-side performance test using EnviroFuels DFC (Diesel Fuel Catalyzer) and LTP (Lubrication Technology Package) on two, diesel-powered EMD 20-645E3 generator sets (gen-sets) used to supply power to a cutter dredge that is owned and operated by a global dredging company. The evaluation examined changes in fuel economy, operational performance, and internal surface conditions of the engines. Fuel economy benefits of nine percent were observed after 60 days of treatment with only DFC. An additional four percent fuel economy benefit was measured with subsequent addition of LTP into the crankcase.

Significant differences in operational performance and internal surface characteristics between the treated and untreated engines were observed after 60 days of treatment with DFC.

This side-by-side engine comparison included a fuel consumption analysis, an engine inspection, and a residue analysis.

Based on the performance of both DFC and LTP in this operational field evaluation, the Global dredging company has implemented DFC and LTP throughout its fleet of dredging equipment.

BACKGROUND

EnviroFuels, LLC (EnviroFuels), headquartered in Houston, Texas, manufactures and markets DFC and LTP. EnviroFuels patented technology reduces harmful combustion emissions while simultaneously increasing engine efficiency and performance. EnviroFuels manufacturers its patented products at two ISO 9001:2000 certified facilities located in Houston, Texas.

EnviroFuels DFC

EnviroFuels DFC is a patented fuel-borne technology that reduces harmful combustion emissions while simultaneously increasing engine performance. DFC is the first stand-alone, EPA-verified technology to reduce emissions and improve fuel economy. These benefits were verified through the U.S. EPA's Environmental Technology Program (ETV).

DFC reduces friction, removes carbon build-up in the combustion chamber, and increases the heat release rate in the combustion chamber of diesel engines. The combination of these positive effects produces significant improvements in fuel consumption and reductions in harmful combustion emissions. DFC is blended into the fuel supply of an engine at a typical treatment ratio of one gallon of DFC for every 1,250 gallons of diesel fuel, or a ratio of 1:1,250 DFC-to-diesel fuel on a volume basis.

A conditioning period is generally required before the benefits of using DFC may be realized. The duration of the conditioning period depends on several factors. First, the condition of an engine greatly affects the length of the conditioning period. If an engine has a high degree of carbon build-up inside the combustion chamber, it will take longer for DFC to clean up the engine before it can reach the surface of the combustion chamber. If an engine is relatively newer or cleaner, it may take less time to realize the benefits of DFC. Second, the fuel flow rate and engine load affect the length of the conditioning period. Since DFC is blended into the fuel stream at a relatively low concentration, higher fuel flow rates and heavier engine loads will have a tendency to shorten the conditioning period by ensuring more DFC is circulated through the engine.

During the conditioning period, fuel economy may slightly degrade as built-up carbon in the combustion chamber is dislodged. Fuel filter change intervals may shorten as they may get loaded with dislodged carbon. The fuel filter change frequency will return to normal once an engine has been cleaned with DFC.

EnviroFuels LTP

EnviroFuels LTP is a patented, premium quality, zinc and chlorine free lube oil treatment that maximizes the performance, protection, and life of engine oil. The patented technology in LTP creates a surface conversion on ferrous and non-ferrous metals using inorganic polymer complexes. These complexes smooth and passivate the metal surface and reduce oxygen reactivity, resulting in a reduction of friction and higher oxidation resistance. LTP is blended into the lubrication oil of an engine. Compared to DFC, LTP has a relatively minimal conditioning period.

Global Dredging Company

The dredging company in this evaluation is the largest provider of dredging services in the United States. Dredging involves the enhancement or preservation of the navigability of waterways or the protection of shorelines through the removal or replenishment of soil, sand or rock. The company’s fleet of equipment includes cutter, hopper, and bucket dredges. The company’s fleet also includes auxiliary equipment such as booster pumps and barges.

Cutter Dredge

The cutter dredge, with shipboard power of over 20,000 horsepower, is the largest cutter suction dredge operating in the United States. A cutter suction dredge is often used in major marine construction projects such as port deepening and beach reclamation.

The cutter dredge is powered by four EMD 20-645E3 turbocharged diesel engines. Two of the engines are primarily responsible for supplying power to the cutter head. These twin gen-sets are capable of generating over four megawatts of power through a common bus. In this single-bus configuration, each engine generates 50 percent of load demand under identical operating conditions. With the engines equally sharing the load and operating at a constant speed of 900 rpms, the generator engines presented a suitable real-time performance monitoring environment. Both engines were in sound mechanical condition with over 31,000 operational hours on each engine since their last overhaul. The two additional engines power the main pumps, in clutch-driven parallel, that transport material through a pipeline.

The evaluation on the cutter dredge was initiated when the dredge was operating in the Port of Miami channel deepening project and concluded with the Freeport, Texas Liquefied Natural Gas (LNG) terminal construction project. The Miami project moved rocky material that heavily loaded the gen-sets and the main pumps were lightly loaded due to short pipeline length. In contrast, the soft material in Freeport demanded a light load from the generators but was transported through over 20,000 feet of pipeline, requiring maximum power from the main pump engines.

TEST PROTOCOL

The test protocol was designed to measure the fuel economy and detergency effects of DFC and LTP. A side-by-side comparison of the generators was mutually determined by the dredging company and EnviroFuels to be the operational environment with the most comparable attributes and fewest external variables. The starboard engines were treated with DFC and then with LTP, while the port engines was left untreated to measure the side-by-side effects of EnviroFuels technology.

This evaluation included five distinct phases:

1. **Baseline Testing:** The engines were evaluated to determine the individual performance characteristics of the starboard and port engines under typical and untreated (or baseline) conditions.
2. **DFC Treatment:** The starboard engine was dosed with DFC. Fuel economy was measured on both the starboard and port engines throughout the conditioning period and extended for a period of 60 days thereafter.
3. **Engine Inspection:** After the fuel economy results were recorded with DFC and LTP, an engine inspection was performed on both the starboard and port engines to compare the differences in engine condition as a result of EnviroFuels' technology.
4. **Residue Analysis:** After the engine inspection, engine residue from the starboard and port engines were analyzed.
5. **LTP Treatment:** After the effects of DFC were documented through the fuel records, the starboard engine was dosed with LTP. The starboard engine continued to be dosed with DFC also. Fuel economy continued to be monitored during the period of treatment with both LTP and DFC.

Additional details regarding each phase of the Global dredging company evaluation is provided below.

Baseline Testing

To measure fuel consumption on each of the main gen-sets, the dredge was equipped with positive displacement flow meters on the fuel supply and return lines of both generator engines. Additionally, a real-time fuel monitoring system was installed to log fuel consumption data continuously. The fuel monitoring system that included the flow meters and monitoring system were accurate to within a ±0.5 percent margin of error, per the equipment manufacturer. The fuel monitoring system recorded instantaneous fuel flow rates and cumulative fuel consumption in both engines at one- minute intervals. Power was measured through GE monitoring software installed onboard the dredge.

Weekly status meetings were conducted between the company and EnviroFuels personnel to monitor any operational or external factors that could impact the trial or adversely impact the field test. Fuel data was jointly analyzed and reviewed at the weekly meeting by both the company and EnviroFuels personnel. The baseline period lasted for one week, during which time the starboard and port engines combined consumed over 20,000 gallons of fuel.

EnviroFuels DFC Testing

The dredge has a main fuel storage tank. Periodically, fuel is transferred from the main fuel storage tank to the various day tanks onboard the dredge. The main engines have their own separate day tanks. The dredge was fitted with an injection system to treat fuel entering the starboard day tank (tank capacity 30,000 gallons) with DFC. The starboard main pump engine was also treated with DFC because of the plumbing design. However, its fuel consumption was not monitored because the clutch mechanism demonstrated a less stable lead-follow relationship rather than a true parallel operation compared to the generators.

Fuel was initially treated for 30 days at the standard 1:1,250 ratio by volume of DFC-to-diesel fuel until excess fuel filter changes stabilized. For the next 30 days the treatment ratio was increased to 1:833 until starboard engine fuel economy improved. The overall cleaning period lasted 60 days.

Ensuring the starboard engines were properly treated with DFC was monitored through four methods. First, fuel consumption volumes by the starboard engines were compared to DFC consumption volumes to see if the injection system was delivering DFC at the proper dosage rates. Second, an ultrasonic flow meter was installed upstream of the starboard day storage tank to measure the rate of fuel transfer into the day storage tank. The DFC injection system is equipped with a positive displacement flow meter to display the flow rate of DFC delivered by the injection system. Using the flow meters for the diesel fuel transfer rate and the DFC transfer rate, the dosing ratio could be verified. Third, a bucket was used to measure the volumetric flow rate of DFC over the period of ten minutes to check the proper dosage rates. Fourth, treated fuel samples were analyzed for physical properties to determine the concentration of DFC in the diesel fuel.

During the entire test period the port engine functioned as a real-time continuous baseline to the treated starboard engine. Thus, it was possible to verify, through engine and vessel logs, that no external factors contributed to changes in fuel economy or engine performance except DFC and, later, LTP.

No-load situations, or when the engines were supplying “house power,” where only one engine is utilized, were excluded from fuel economy comparisons.

Engine Inspection
After the 60-day treatment period with DFC and prior to commencement of the Freeport project, a mechanical inspection of both the treated and untreated generator engines provided the basis for a side-by-side comparison of the effects of DFC on engine cleanliness. The engine inspection was performed by a qualified EnviroFuels engineer with over 30 years of experience servicing EMD engines and dredging company personnel to observe the extent of detergency and surface conversion benefits of the treated starboard engine. Photographs of various engine components were taken as documentation of the effects of DFC.

Residue Analysis
During the engine inspection, samples of engine residue were taken and sent to a laboratory for chemical analysis. The chemical analysis of the engine residue was used to determine if there was any difference in the composition of residue between the untreated and treated engine that may have resulted from the application of DFC.

EnviroFuels LTP Testing
After the engine inspection, the two inspected power packs on each engine that were examined during the engine inspection were replaced per the company’s planned maintenance schedule. After the power packs were replaced, the cutter dredge returned to revenue service. When the dredge returned to service, the starboard engines continued to be treated with DFC. Additionally, the starboard engines were treated with LTP.

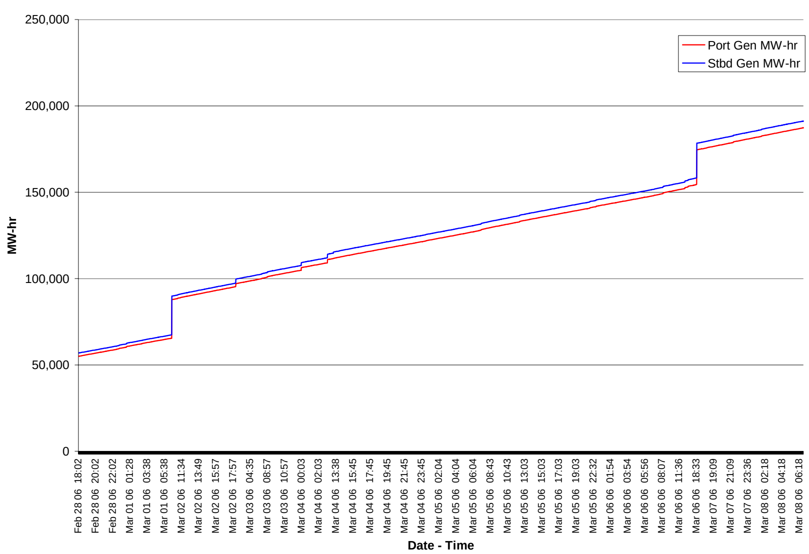
The lube oil was initially treated at an LTP-to-lube oil volume ratio of 1:32 in the crankcase or one gallon of LTP for every 32 gallons of lube oil capacity. Company personnel also add make-up oil to the crankcase daily. The daily make-up oil was dosed at maintenance ratio of LTP-to-lube oil ratio of 1:125 by volume.

RESULTS

During the baseline period, prior to initiating DFC treatment, the starboard engine was observed to consume 2.4 percent more fuel than the port engine over a period when each engine consumed nearly 10,000 gallons of fuel. Despite the fact that the starboard and port engines equally share the load of the dredging activities, the fuel monitoring system confirmed that there was an initial difference in efficiency between the engines. Company engineers suggested that the performance difference between the two engines could be contributed to the fact that there was significant blockage on the starboard engine's turbocharger screen due to carbon deposits.

Figure 2 shows the output from the GE power monitoring software. The data showed that the starboard and port engines produced the sample power output to within ±1 percent. Verifying that the engines were operating in parallel and properly load-sharing was important so that any significant changes in engine performance could have been attributed to the effects of DFC and LTP. It should be noted that, in Figure 2, the vertical line shifts represent corrections in cumulative power production after periods when only one engine was operating or supplying house power.

Figure 2: Verification of Load Sharing Between Starboard and Port Engines



EnviroFuels DFC Results

After 60 days of treatment with DFC and approximately 85,000 gallons of fuel consumption per engine, the starboard engine started a consistent trend towards consuming less fuel than the port engine. Figure 3 shows the percent difference in fuel consumption between the starboard and port engines for every 10,000-gallons of fuel consumption on the starboard engine. The baseline difference in engine performance between the starboard and port engine of 2.4 percent is also shown in Figure 3.

The data from the fuel consumption analysis is summarized in Table 1. The fuel monitoring system recorded instantaneous fuel consumption rates during the evaluation at one-minute intervals. Thus, the overall consumption for each engine was calculated by multiplying the fuel consumption rate by the interval time, or one minute. The average percent difference in fuel consumption between the two engines was calculated by averaging the percent difference between the fuel flow rates.

Figure 3: Percent Difference between Starboard and Port Engines for Every 10,000-Gallon Interval

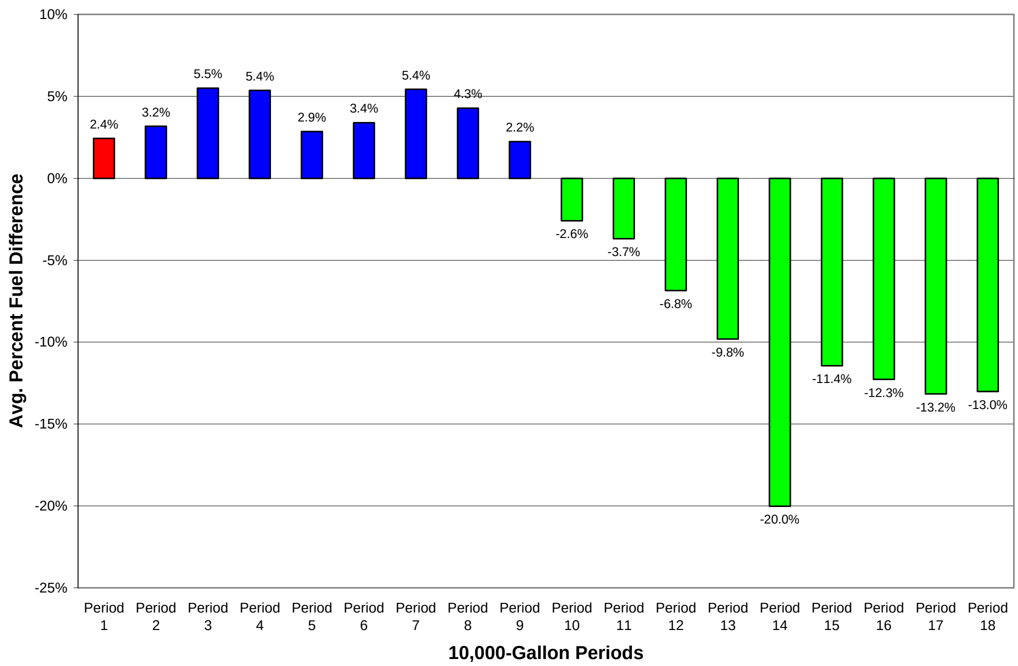


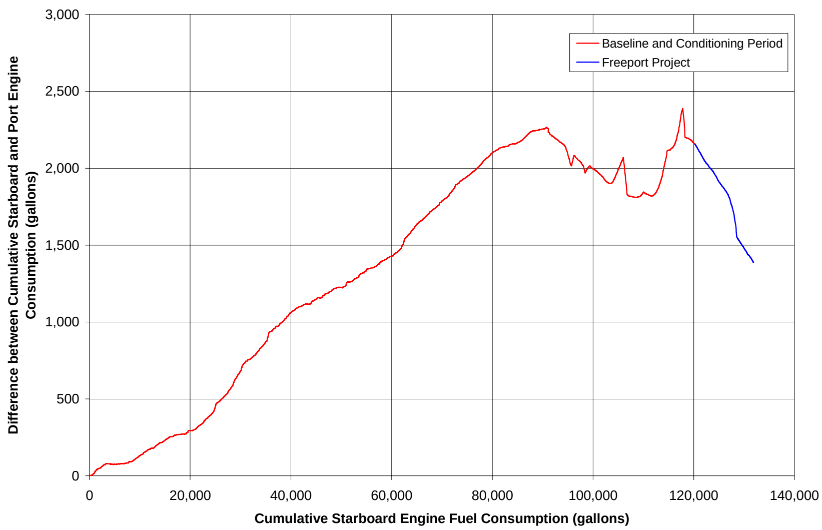
Table 1: Fuel Consumption Data for Cutter Dredge

Period	Port Engine Untreated (gallons)	Starboard Engine Treated (gallons)	Percent Difference
1	9,451	9,570	2.4%
2	9,832	10,001	3.2%
3	9,630	10,003	5.5%
4	9,601	9,987	5.4%
5	9,819	9,999	2.9%
6	9,807	10,003	3.4%
7	9,646	9,999	5.4%
10	10,247	10,001	-2.6%
11	10,187	10,007	-3.7%
12	9,996	9,341	-6.8%
13	11,139	10,001	-9.8%
14	12,621	10,002	-20.0%
15	10,000	8,882	-11.4%
16	10,003	8,762	-12.3%

With DFC treatment alone, the starboard engine ultimately consumed 6.8 percent less fuel than the untreated Port engine per 10,000-gallons of fuel consumption by the starboard engine. Compared to the baseline, the starboard engine, or treated engine, consumed 9.2 percent less fuel over the final 10,000-gallon fuel consumption interval of the evaluation.

During the baseline period, the starboard engine consumed more fuel than the port engine as displayed in Figure 2. Through treatment with DFC, the treated engine, starboard, reversed a historical trend of greater fuel consumption and then consumed significantly less fuel than the untreated engine, port. The volumetric fuel consumption differential between the starboard and port engine is displayed in Figure 4.

Figure 4: Overall Consumption Difference between Starboard and Port Engines



Engine Inspection
Visual observations of both engines were performed on-site and residue samples were collected for laboratory chemical analysis after 60 days of treatment with DFC.

The untreated port engine, operating in parallel and with identical hours and duty cycle to the treated engine, served as the baseline engine. Cylinder positions No. 4 and No. 15 were opened for observation. The liner serial numbers, an indicator of manufacture date, were 98H051 (September 1998) and 99H004 (September 1999), respectively. Thicker medium piston crown deposits were found in the untreated engine. Samples of the deposit residue were taken.

On the treated starboard engine, cylinder positions No. 8 and No. 15 were opened up by head removal. The liner serial numbers for positions No. 8 and No. 15 were 98H038 (September 1998) and 99H062 (September 1999), respectively, indicating that the cylinder liners of the port and starboard engines at these respective positions were the same age. The airbox exhibited a light oily surface without excessive carbon build-up. Piston crowns were encrusted, but dry. There were medium deposits on the treated engine's firing faces and in the exhaust valve cups. Samples of the deposit residue were taken.

The injector tips on each engine had carbon deposit build-up consistent with the firing face on each engine.

The following differences were observed between the starboard and port engines and were attributed to treatment with DFC:

Cleaner Exhaust Ports

- The treated starboard exhaust ports on the head appeared smoother, suggesting carbon deposit removal and reduced build-up was occurring.
- The difference was subtle, but noticeable, despite only 60 treatment days with DFC relative to the extensive operating hours at the comparison test start date (over 31,000 hours).
- Improvement is most evident by comparing smooth, dull gray surfaces of the starboard engine to layered, glossy, black surfaces of the port engine.
- Figure 5(a) through Figure 5(d) show the difference in carbon build-up of the exhaust ports.

Figure 5(a): Treated Exhaust Port No. 15

Figure 5(b): Untreated Exhaust Port No. 15

Figure 5(c): Treated Exhaust Port No. 8

Figure 5(d): Untreated Exhaust Port No. 4

Improved Liner Ring

- The upper cylinder liner surfaces of the treated starboard engine demonstrated similar evidence of DFC activity.
- The treated engine had cleaner liner surfaces above ring reversal (annulus) as evidenced by Figure 6(a) and Figure 6(b).

Figure 6(a): Treated Cylinder Liner Ring Reversal

Figure 6(b): Untreated Cylinder Liner Ring Reversal

Less Turbo Screen Maintenance

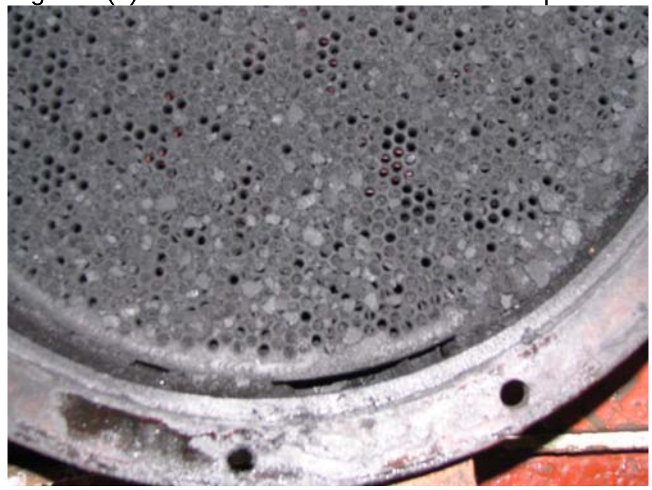
- The turbo screen of the treated starboard engine showed reduced carbon build-up, particularly at close-up view, compared to the untreated port engine.
- Figure 7(a) through Figure 7(d) show a comparison of the turbo screens.

Figure 7(a): Treated Turbo Screen

Figure 7(b): Untreated Turbo Screen

Figure 7(c): Treated Turbo Screen, Close-Up

Figure 7(d): Untreated Turbo Screen Close-Up



Smoother Valve Seats

- The heads of the treated starboard engine showed less carbon residue build-up between the valves and valve seats, as evidenced by Figures 8(a) and Figure 8(b).

Figure 8(a): Treated Head No. 8

Figure 8(b): Untreated Head No. 15

Combustion Chamber Residue Analysis

The results of the elemental analysis of the engine residue from each engine showed a higher ratio of carbon-to-hydrogen on the treated starboard engine after 60 days of treatment with DFC.

The spectral analysis also showed the concentrations of elements present in the engine residue of the two engines:

- The calcium concentration of the residue from both the untreated and treated cylinders was approximately 300-400 parts per million (ppm).
- The phosphorus concentration was approximately 20 ppm in both samples.
- No other significant levels of metals, including iron, were detected.
- The silicon levels were extremely low, thus, confirming that the residue was not dirt.

- The remaining non-metallic portions of the residue were primarily carbon, hydrogen and nitrogen.

The presence of calcium was most likely residue from the combustion of the high-ash lube oil that wicks up into the combustion chamber from the crankcase. High oil consumption exacerbates this phenomenon. Calcium levels were about the same on both the treated and untreated samples. However, the treated residue was lighter in color and had no odor. The untreated residue was dark and had a burnt odor. This type of residue is indicative of deposits that tend to layer up continuously over time and eventually degrade to coke.

The amount of phosphorous detected likely came from the lube oil. While DFC does contain amounts of phosphorous, the phosphorous present in DFC would be present in lower concentrations than the phosphorous present in the lube oil.

The comparison of carbon, hydrogen, and nitrogen present in the residue samples is presented in Table 2.

Table 2: Elemental Analysis of Engine Residue

Engine	Weight Percent			C/H Ratio
	Carbon	Hydrogen	Nitrogen	
Port (Untreated)	18.82%	2.32%	<0.3%	8.11
Starboard (Treated)	8.55%	0.75%	<0.3%	11.40

The above data showed that DFC removed carbon-containing compounds from the treated engine's residue sample. The difference between the levels of the two engines suggested that there was a detergency benefit exhibited by treated engine.

EnviroFuels LTP Results

After DFC benefits were documented, the dredge was relocated to a different project. The starboard engines continued to be treated with DFC at the ratio of 1:1,250 DFC-to-diesel fuel. At the onset of the new project, however, the starboard engines were treated with LTP in the crankcase at an initial treatment volume ratio of 1:32 (LTP-to-lube oil). After the initial treatment, daily make-up oil was treated with LTP at a daily maintenance volume ratio of 1:125 (LTP-to-lube oil).

After one week of treatment with LTP, an additional four percent fuel economy improvement was measured. During the initial week of treatment with LTP, oil filters were changed twice as often; but, the oil filter change interval stabilized thereafter.

Oil samples were analyzed throughout the evaluation, including the DFC test, to ensure that no mechanical problems affected the operation of the dredge or the outcome of the evaluation.

SUMMARY

The evaluation of DFC and LTP on an EMD 20-645E3 generator set used to supply power to dredging activities on the cutter dredge, a Global dredging company cutter dredge, showed fuel economy improvements and significant removal of carbon build-up in the engine.

After 60 days of treatment with DFC, the treated starboard engine exhibited a nine percent fuel economy improvement compared to the baseline period as measured by fuel consumption over 10,000-gallons of fuel consumption while the engines supplying power to dredging activities. An additional four percent fuel economy improvement was realized in 7 days with the subsequent addition of LTP into the lube oil of the crankcase.

After two months, or 1,500 hours, of treatment with DFC, the treated starboard engine showed evidence of significant reduction in the amount of carbon build-up that had been generated over the course of 31,000 operational hours. In comparison to the untreated port engine, the observed detergency effects of DFC suggests additional preventative maintenance benefits may be realized by removing oxidized hydrocarbons that result from the combustion process inside the engine.

Through fuel monitoring records, photographs taken from the engine inspection, and engine residue analysis, DFC and LTP demonstrated the ability to improve fuel economy by fourteen percent and to reduce the amount of hydrocarbon build-up in a diesel engine with over 31,000 operational hours.