Evaluation of Fuel Additives - FA-6048 Onboard A Major Cruise Ship Line

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SUMMARY TEST RESULTS:

MAIN ENGINES:

The main engine Carbon Mass Balance results were:

- Fuel Efficiency 4.9% increase
- RPM 1.4% reduction
- Exhaust Temperature 3.2% reduction
- CO 14.4% reduction
- HC 23.4% reduction
- CO2 5.4% reduction
- O2 2.9% increase

AUXILIARY ENGINES:

The auxiliary engine Carbon Mass Balance results were:

- Fuel Efficiency 15.3% increase
- CO 10.4% reduction
- HC 10.9% reduction
- CO2 2.9% reduction
- O2 2.8% increase

BOILERS:

The boiler Carbon Mass Balance results were:

- Fuel Efficiency 16.6% increase
- CO 3% reduction
- HC 33% reduction
- CO2 4% reduction
- O2 17% reduction

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Fuel Oil Blending

Product "FA-6048" removes pollutants inside the combustion chamber while the fuel oil burns. "FA-6048" is one of the safest, most cost-effective pollution control technologies available. "FA-6048" means clean combustion, clean combustion means clean air and clean engines.

Reducing Maintenance

In heavy fuel oil engines, fuel characteristics have a significant impact on deposit formation. Negative fuel characteristics cause problems with corrosion, wear, deposit formation, and injection systems. For example:

- High sulfur content causes corrosion and wear at low speeds.
- High ash content causes abrasive wear, high-temperature corrosion and contributes to deposit formations.
- High vanadium content causes hot corrosion on exhaust valves particularly in combustion with high sodium content.
- High sodium content contributes to corrosion on exhaust valves.
- High water content may cause problems in the engine fuel injection system.

Additionally, heavy fuels usually have very low ignition quality at low load operation. Viscosity, although not a criterion of fuel quality, may determine the complexity of the fuel heating and handling systems.

In boilers, "FA-6048" reduces fireside deposits. Fireside deposits decrease the rate of heat transfer, resulting in increased stack temperatures and decreased burn efficiency. Boiler downtime caused by deposits and corrosion, result in the loss of profit because of reduced production while making repairs. The magnitude of this loss if often under estimated.

Fireside fouling and corrosion are principally caused by impurities present in heavy fuel oil, and as in diesel engines, the most commonly found problem elements are sulfur, vanadium, and sodium. For example:

- Typically, sulfur at low temperatures contributes to acid attack in boilers.
- Vanadium and sodium at high temperatures contribute to acid attack and deposits in boiler tubes.

"FA-6048" is a proven burn rate and surface modifier. It prevents deposit build-up on all types of combustion surfaces. Existing deposits on mobile or stationary equipment are rapidly modified and removed. The catalyst is effective in diesel, heavy fuel oil, and coal applications. Combustion after the use of "FA-6048" receives a *four-to-twenty percent increase in burn efficiency and a five-to-thirty percent reduction in emissions, depending on the application.*

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*TESTING "**FA-6048**" ON BOARD A MAJOR CRUISE SHIP LINE*

The test was conducted onboard ship during regularly schedules voyages, with departures and returns to Miami, Florida.

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This ship makes regular one week voyages out of Miami. The Captain, the Chief Engineer, and the complete Engineering staff were responsible for ensuring the stability of the test results taken during our trips on the ship and we owe them our thanks.

Equipment Tested

The ship has four (4) main engines for propulsion, six (6) auxiliary engines for power generation and two (2) boilers for steam generation.

Main Engines:

The ship uses four (4) SEMT-Pielstick PC 20 L nine (9) cylinder engines rated at 5,515 kW (6,967hp) at 450 rev/min, giving a total output of 22,060kW (27,828hp) on two shafts.

Auxiliary Engines:

The ship uses six (6) Wartsilla engines (gensets) used for power generation and are rated at 2,300kW (3,000hp), giving a total output of 13,800kW (18,000hp).

Boilers:

The ship uses two (2) Saacke Duoblock Rotary Cup Burners with a burner capacity of 6,791MW, giving a total output of 13,582MW.

Boiler #1 burns the same heavy fuel oil used by the main and auxiliary engines and is used to provide supplementary requirements for steam.

Boiler #2 burns sludge from the main fuel storage tanks and waste oil products and is used to dispose of the sludge and waste oil products as well as to provide supplementary steam.

Tests Used

The test was conducted using three methods: The Carbon Mass Balance Procedure, Laboratory Tests of Fuel and Deposit Samples, and a Visual Observation of Engine and Boiler Deposits taken before and after the test.

Carbon Mass Balance Procedure

The Carbon Mass Balance Procedure has been recognized by the US Environmental Protection Agency (EPA) since 1973. This method relies on the measurement of exhaust emissions to determine fuel consumption rather than direct measurement (volumetric or gravimetric) of fuel consumption.

Between June and September, three (3) Carbon Mass Balance Procedures were run with the final procedure taking place during the week if September.

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Laboratory Tests

Laboratory tests were conducted on fuel and deposit samples taken from onboard the ship during the test period. These tests were used to determine the changes in the metal content and reductions of carbon in the ash, changes in the chemical compounds obtained during test burns and the chemical complexity of the residue build-up on the main engine valves.

A large number of laboratory tests were completed. These tests included the following samples:

- *Untreated* heavy fuel bunker on board the ship from June19th – August 2nd.
- *Treated* (with "FA-6048" fuel taken from the storage tank onboard ship with a mixing ratio of 1:5000 and 1:10,000).
- Deposit samples taken from boiler #1 tubes prior to the use of "FA-6048" – fuel is the heavy fuel after separation process.
- Deposit samples taken from boiler #1 tubes while using "FA-6048" – fuel is the heavy fuel after the separation process.
- Deposit samples taken from boiler #2 boiler tubes prior to the use of "FA-6048"- sludge fuel.
- Deposit samples taken from boiler #2 boiler tubes while using "FA-6048" – sludge fuel.
- Deposit samples taken two (2) weeks after boiler #2 was shut down for regular preventative maintenance.
- Deposit samples taken in June from the exhaust valve stem off ME #1 cylinder 3 that was taken out and replaced.
- Deposit samples taken in September from the exhaust valve stem of ME #1 cylinder 3 that was installed on June.
- Deposits taken from sites in the exhaust stacks on August and September.

Visual Observation

A visual check was made of main engine (ME#1) exhaust valve deposit build-up, of auxiliary engine (AE#2) deposit build-up and of the reduction of slag on both boilers after the test. Samples from the boiler walls, taken throughout the test, were preserved for laboratory testing, and so the difference could be seen. Additionally, the particulate filters that were used in the Carbon Mass Balance were retained after the June and September tests. Photographs are shown of these in EXHIBIT "A".

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*Overall Impact of "**FA-6048**"*

"**FA-6048**" improved the combustion efficiency, reduced emissions, reduces carbon build-up on surfaces, reduced slag and soot deposits on boiler surfaces and reduced maintenance. This test showed that "FA -6048" is effective in the problems related to vanadium and sulfur, and at the same time reduces excess air requirements for proper combustion.

*The test showed the benefits of using "**FA-6048**" are:*

- **Reductions of unburned carbon**
- **Reductions in slag build-up**
- **Reductions in the number of burned exhaust gas valves**
- **Reductions in the deposits in the turbo chargers for the engines**
- **Reductions of soot in the exhaust gas boilers and oil filled boilers**
- **Reductions in NOx emissions**
- **Reductions in SOx emissions**
- **Reductions in COx emissions**
- **Reductions in exhaust gas temperatures**
- **Increased heat transfer throughout the combustion system**
- **Increased energy produced per ton of fuel**

"FA-6048" provided gains in combustion performance of 4.9 percent on the main engines, 15.3 percent on the auxiliary engines and 16.6 percent in the boilers through:

- **A more efficient fuel burn**
- **A cleaner burn with less particulate and other harmful emissions.**

The following provides a closer look at these benefits and why they were obtained.

Reductions of Unburned Carbon

Unburned carbon is a loss of energy and dollars. According to the Carbon Mass Balance test, fuel savings were 4.9 percent for the main engines overall, 15.3 percent for the two auxiliary engines tested and 16.6 percent for the two boilers. During a laboratory test burn of fuel taken from the ship, the carbon content of the ash from the treated fuel was reduced by an average of 37.9 percent. This is a direct result of the catalytic process of "FA-6048" which lowers the ignition temperature of carbon by approximately 400 degrees, thereby increasing the residence time of the burn. Additionally, "ADA" has a polymerization inhibitor which prevents fuels after they are "cracked" at the refinery, from restructuring into long molecule carbon chains which are harder to burn.

The reduction of unburned carbon was also apparent from the reduction in smoke during maneuvers.

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Reductions in Slag Build-up

Photographs were taken of the slag taken from boilers #1 and #2 (sludge boiler) on board the ship. Some were taken both before and after the test. These photographs are shown in EXHIBIT "A". The boiler was cleaned in May. It took significant time and effort to clean it, and the boiler was down for seven (7) days. Two months later, after three (3) weeks of using "FA-6048" the boiler was cleaned again. The deposits were much softer and easier to remove, and the cleaning took only three (3) days. Only small deposits were present on the boiler tubes. In September the boiler was cleaned again. The cleaning, and repairs to the soot blower, took one and one-half days. The bottom deposits were very soft and there were no deposits on the walls or tubes.

With "FA-6048", reduced slag is accomplished by decreasing the combustible carbon residue present in the slag and by providing an injection into the fuel of a catalytic compound (proprietary component), which provides more free radicals to enter into the combustion process and form high melting point vanadium compounds. These higher melting point compounds become fly ash. The ash goes up the stack. The slag produced contains very few low-melting point sulfate deposits such as, sodium vanadyl sulfate. This deposit is light, powdery and contains less carbon and can easily be removed by brushing or water washing. The small amounts of carbon in the combustion **chamber act as "glue" to bong the slag materials to the steel, but this remaining carbon will continue to be** combusted further reducing the build-up on the combustion walls.

Reductions in the Number of Burned Exhaust Gas Valves

Laboratory tests on the residue from an exhaust valve body and stem were conducted after the test. The test showed a 71.5 percent reduction of the carbon in the residue, "the glue", on the exhaust valve stem removed from ME #1 on September as compared to the exhaust valve stem removed from that same engine and same cylinder on June 11th. There was a reduction of 2.0 percent of the carbon in the residue on the valve body. The scoring on the face of the valve removed on September 15th was noticeably different than the valve removed before the test began. The reduction in the mass of residue on the exhaust valve stems, exhaust valve bodies and on the valve face seats into the valve seat in the cylinder head was quite apparent. The removal of this residue was much easier, since it did not adhere to the surfaces. This reduction in the build-up was also noticed where other exhaust valves were removed throughout the test. The chemistry involved when "FA-6048" is used, slows the formation of sodium vanadly sulfate which combines with the soot to create a hard build-up. This is explained in the ***Reduction in unburned carbon above and Reductions of soot in the exhaust gas boilers and oil fired boilers*** which follows:

Reductions in the Deposits in the Turbo Chargers for the Engines

When a turbo charger was opened for inspection on the ship, it was clean and was closed up without any maintenance. Deposits in the turbo chargers are normally a gummy residue caused by slobbering on the intake valve when it opens after the combustion stroke. A small amount of unburned fuel and ash in the combustion chamber is dispersed back into the exhaust throat of the turbo charger. Because of the more complete combustion of the fuel as explained above in ***Reductions in unburned carbon*** and the polymerization inhibitor in "FA-6048"which prevents the hydrocarbon molecules from restricting into bigger chains, there is less residue available for unintentional return to the turbo charger.

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Reductions of Soot in the Exhaust Gas Boilers and Oil Fired Boilers

Since the ship began using "FA-6048" there has been a significant reduction in soot. A reduction in soot results in less downtime to "blow soot" and clean surfaces. Before "FA-6048" the boilers were blown at least twice per day using two or three attempts each time to reduce pressure. Near the end of the test, the boilers were 'blown' once each day in one attempt. Additionally, the back pressure is now much easier to maintain. The exhaust gas was able to be cleaned down to bare metal using only high pressure steam. The reduced and softer soot came off easily.

Since carbon insulates five to ten times better than asbestos, a reduction in soot means improved heat transfer and additional gain in BTU's.

Reduction in NOx Emissions

Reductions on NOx were not measured, but a reduction in the harmful emissions of NOx will be achieved. Complete combustion requires less excess air because of the lower ignition temperature as described on the previous page. With less air required, there is less nitrogen fixation. The engineering staff on board the ship has some control over these air requirements.

Reduction in SOx Emissions

Sulfur in is Sulfur out, either gaseous emissions or ash. The combustion of sulfur in fuels almost invariably leads to the formation of sulfur dioxide and sometimes sulfur trioxide in gaseous emissions. The metals in the fuel react with the sulfur trioxide or sulfuric acid present to form mixed metal sulfates which show up in the particulate portions of the combustion products. The more sulfur in the particulate, the less sulfur in the gasses.

"FA-6048" does not react with sulfur in the fuel nor does it have any effect on the sulfur content of the fuel. "FA-6048" stops or slows the formation of gaseous sulfur emissions from occurring by promoting the formation of stable mixed metal sulfates thus shifting the gaseous sulfur emissions to the particulate portions of the combustion products. No tests were run on sulfur emissions, but the catalytic effect provided by "FA-6048" provides the free radicals necessary to promote the formation of the mixed metal sulfates that have high melt points. The particulate matter from "FA-6048" treated fuel oil therefore will show a slightly higher sulfur content than the particulate matter from the untreated fuel oil.

Reduction in COx Emissions

Carbon monoxide was reduced by 14 percent (14%) on the main engines, 10.4 percent (10.4%) on the auxiliary engines, and 3 percent (3%) on the boilers. Carbon dioxide was reduced by 5 percent (5%) on the main engines, 10.9 percent (10.9%) on the auxiliary engines, and 4 percent (4%) on the boilers. This reduction results from increasing the completeness of the combustion through lower ignition temperatures. Less available carbon through better combustion results in less carbon monoxide.

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Reduction in Exhaust Gas Temperatures

Main engine exhaust gas temperatures were reduced by 3.2 percent (3.2%). Vanadium and sodium are high temperature problems that contribute to hot corrosion on exhaust valves. In boilers, reduces the need for excess air thus lowering stack temperatures. Additionally, "FA-6048" also burns off existing carbon deposits to further reduce stack temperatures. The improvement in stack temperature is a direct result in the improvement in heat transfer, reduction in hydrocarbons, and improved combustion through the use of "FA-6048".

Increased Heat Transfer throughout the Combustion System

Carbon deposited on the surface has five to ten times more the thermal insulating valve of asbestos and significantly reduces heat transfer. The more complete combustion of hydrocarbons with "FA-6048" provides improved fuel efficiency and reduction in carbon deposits and emissions as explained in ***Reductions of Unburned Carbon.*** This results in increased heat transfer.

Hydrocarbon emissions, a measure of unburned fuel and carbon deposits, decreased dramatically on all equipment. On the main engines HC reductions were 23 percent (23%), on the auxiliary engines 10.9 percent (10.9) percent and on the boilers 33 percent (33%). The Carbon Mass Balance uses a 25 micron filter to trap particulate matter. The photographs taken of the filters used on the main engines are shown in EXHIBIT "A" and show the tremendous reduction in particulate size which correlates to a reduction in soot and smoke.

Increased Energy Produced per ton of Heavy Fuel Oil

The percent of metals in the soot in relation to the percent of carbon increased during the test showing an increase in the combustion efficiency. The main engines averaged an increase of 4.9 percent (4.9%). "FA-6048" treated hydrocarbon fuels have lower ignition temperatures – normally about 400 degrees Fahrenheit below the average. The lower ignition temperatures allow carbon to burn at 800 degrees Fahrenheit versus 1,200 degrees Fahrenheit. Therefore, larger particulate will burn more completely during the same residence time. "FA-6048" reduced the effluent particulate size to less than 25 microns as shown by the Carbon Mass Balance which uses a 25 micron filter to trap particulate matter. The catalyst provides a more complete combustion of these larger particles, resulting in more usable energy and a reduction in LOI. This indicates a significant improvement in combustion providing more BTU's.

Specific Test Results

The tests were conducted to determine: Fuel economy increase, emission reductions, and engine and boiler deposit reductions (reductions in maintenance). Estimated overall fuel economy increases and emission reductions are shown by use of the Carbon Mass Balance procedure and laboratory testing. Engine and boiler deposit reductions are shown by laboratory testing and visual inspection.

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CARBON MASS BALANCE PROCEEDURE

Several Carbon Mass Balance tests were conducted onboard the ship, three times during the test June 19 – September 18. Only the results of the baseline in June and the final test are shown in the table below. These tests were performed on all the SEMT Pielstick main engines, Two (2) of the Wartsila auxiliary gensets (AE #2 and AE #5), and both of the Saache Duoblock Rotary Cup Burners (boiler #1 and boiler #2).

The Carbon Mass Balance uses a 25 micron filter to trap particulate matter. "FA-6048" reduced the effluent particulate size to less than 25 microns, indicating a significant improvement in combustion producing more BTU. The photographs taken of the filters used on the main engines are shown in EXHIBIT "A" and show the tremendous reduction in particulate matter that was able to be trapped by the filters. Because of this the fuel efficiency gains shown by the Carbon Mass Balance where:

- Main Engines 4.9%
- Auxiliary Engines 15.3%
- Boilers 16.6%

The expected fuel economy increased for the ship as determined by the Carbon Mass Balance procedure was over 4.9 percent (4.9%). Actual improvements cannot be determined for many months because of the following factors:

- Currents
- Weather Patterns
- Load Factors
- Route

The detailed results of the Carbon Mass Balance Procedure for the baseline and final analysis run on the ship are shown on the following pages.

The Carbon Mass Balance Procedure showed reductions in the exhaust temperatures, CO, HC and CO2 and increases in O2.

The results for the Carbon Balance Procedure for the engines and boilers are shown on the following pages. The first results show changes in exhaust temperature which will result in less maintenance. The second results show the reduction in the main engine RPM since the beginning of the test. The final results show emission reductions for the main and auxiliary engines and boilers.

With continued use of "FA-6048" the reductions to date can be expected to continue with the elimination of existing carbon deposits and no further build-up.

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MAIN ENGINES: [(4) SEMT – Pielstick PC 20L Nine (9) Cylinder Engines Rated @ 5,515kW (6,957hp) @ 450 REV/MIN, Total output 22,060kW (27,828HP) on Two Shafts.]

The main engine Carbon Mass Balance results were:

- Fuel Efficiency 4.9% increase
- RPM 1.4% reduction
- Exhaust Temperature 3.2% reduction
- CO 14.4% reduction
- HC 23.4% reduction
- CO2 5.4% reduction
- O2 2.9% increase

AUXILIARY ENGINES: [(6) Wartsila Engines (Genset) Rated @ 2,300kW (3,000HP), Totaling 13,800kW (18,000HP).]

The auxiliary engine Carbon Mass Balance results were:

- Fuel Efficiency 15.3% increase
- CO 10.4% reduction
- HC 10.9% reduction
- CO2 2.9% reduction
- O2 2.8% increase

BOILERS: [(2) Saacke Duo Block Rotary Cup Burners with a burner capacity of (6,791 MW) Total output of 13,582 MW.]

The boiler Carbon Mass Balance results were:

- Fuel Efficiency 16.6% increase
- CO 3% reduction
- HC 33% reduction
- CO2 4% reduction
- O2 17% reduction

Laboratory Tests

During the test, samples of fuel, soot, slag, and carbon deposits from combustion surfaces were sent to a laboratory for testing. A brief summary of the results for the sample deposits taken are include below:

- A 37.9 percent (37.9%) reduction in the amount of ash from untreated to "FA-6048" treated fuel.
- A 4 percent (4%) reduction, averaged in the carbon in the soot taken from site plugs on the main and auxiliary engine stacks between August 2, and September 13. **The first sample was obtained after "FA-**

6048" had been in use for six weeks, so substantial reductions in particulate size had already been achieved.

- A 71.5 percent (71.5%) reduction of carbon in the soot accumulation on the exhaust valve stem removed from ME #1 on September 15, as compared to the exhaust valve stem removed from that same engine on June 11.
- A 2.0 percent (2.0%) reduction of carbon in the soot accumulation on the exhaust valve sleeve removed from the ME#1 on September 15, as compared to the exhaust valve sleeve removed from that same engine on June 11.

Visual Observations

Visual inspection tests were used to verify engine and boiler deposit reductions. Photographs are included in EXHIBIT "A" which show:

- Filters from before and after the test which show reductions in the particulate matter size from the exhaust of the main engines.
- Slag formation residue taken from the boiler, before and after the test, which show how its properties have changed.
- Exhaust valves from the main engines before and after the test which show less torching and less carbon build-up.

These photographs show that with the use of "FA-6048" there are major reductions in particulate matter emissions, reduced formation of sodium vandal sulfate, less torching of the valves, and less carbon build-up through more complete combustion.

On September 11, auxiliary engine #2 was R&R'd. The total hours on the engine were 17,192. The total hours since last overhaul on this engine were 4,148. A reconditioned head was used on the previous overhaul in February. The small amount of carbon that was found during the overhaul was much softer and easier to remove.

Boiler walls and tubes have no build-up of slag since the use of "FA-6048" therefore boiler maintenance has decreased substantially. It is easier to maintain back pressure levels and mixing of sludge with higher quality fuel has declined.

With the valued assistance of "FA-6048", a cylinder head was changed in main engine #1 prior to beginning the test. The cylinder head was removed at the end of the test and an exhaust valve was compared with the one removed at the beginning of the test for its condition and deposit build-up (see photos). Residue on the spindles was much softer and easier to remove.

Items noted during and since the end of the test are:

- Valves have less build-up of hard deposits and what is left can be easily cleaned.
- Valve replacements are less frequent except for normal preventative maintenance.
- Man and Auxiliary engine components, when maintenance is performed, clean much more rapidly and with less effort.

- Exhaust gas boilers have very little build-up of residue and can be cleaned with only high pressure water.
- Water sight gauge on fuel tank is continually rising, which means the water is separating out of the fuel better with "FA-6048's" demulsifier.
- More sludge is being burned than ever before.
- Sludge boiler ignites on first attempt after back blowing.
- Back blowing of the boilers to lower pressure has become a once a day task, accomplished in a single attempt.
- Boiler pressure is easier to maintain.
- Boiler maintenance time has decreased greatly from 7 days to 1 day.
- The use of other products for cleaning boilers can be reduced.

Based on assurances from the photographs, the combustion surfaces had significantly less deposit build-up than normal. As these surfaces continue to improve through the use of "FA-6048", fuel economy will improve, harmful emissions will decrease, and engine maintenance will decrease as well.

Meeting Expectations

Expectations and results:

- Reduce the number of burned exhaust gas valves:

  - ✓ The First Engineer stated at the end of July, that the replacement of exhaust valves had decreased in the last few weeks.

  - ✓ He also stated that what little deposits that were found were much easier to remove. Some of the parts, including valves, did not have to be put into the vat for cleaning, and if they were, they only had to stay a short time to be cleaned.

  - ✓ Photographs of exhaust valves are shown in EXHIBIT "A". The photographs show an exhaust value taken from ME #1, cylinder #3 before the test began and the exhaust valve removed from the same engine and cylinder at the conclusion of the test. The photographs show the major reductions in build-up with the use of "FA-6048"

- Reduce the deposit in the turbo chargers for the engines:

  - ✓ When a turbo charger was opened for inspections on the ship, it was cleaned and closed up without any maintenance.

- Reduce the smoke from the main engines during maneuvers:

  - ✓ The Carbon Mass Balance uses a 25 micron filter to trap particulate matter. The photographs taken of the filters used on the main engines are shown in EXHIBIT "A" and show the tremendous reduction in particulate size.

- ✓ Visual inspection of the exhaust from the stacks showed significant reductions in smoke.

- Reduce the soot in the exhaust gas boilers:
  - ✓ Statements by the Second Engineer and the Motor Man, confirm that there are no deposits on the tubes and that the bottom deposits are very easy to remove.
  - ✓ The number of times per day to back blow the boilers to low pressure was reduced from many times per day in the past to once per day.
  - ✓ Visual observation by the Second Engineer noted a positive difference in the boiler flame after the treated fuel reached the boiler on day one of the test.
  - ✓ The Motor Man assigned to the boiler stated that "FA-6048" made his job much easier.

- See the difference in the emission before and after the use of:
  - ✓ The Carbon Mass Balance Procedures have shown reductions in carbon monoxide, carbon dioxide, hydrocarbons and increases in oxygen levels for all main engines, auxiliary engines and boilers.
  - ✓ Lab tests have shown that "FA-6048" treated fuel provides a 37.9 percent (37.9%) reduction in the ash.
  - ✓ Visual inspection of the exhaust from the stacks shows significant reductions in smoke.

SUMMARY

From the time "FA-6048" is added to the bunkered fuel it begins to provide savings. By placing "FA-6048" in the bunkered fuel there is more time for its active ingredients to work on the fuel. When the fuel reaches the separators some of the moisture is already removed and the separators will have an easier time separating the remaining moisture and contaminants. "FA-6048" provides a demulsifier that immediately starts to remove moisture from the fuel, a polymerization inhibitor to prevent a molecular "chaining" of the hydrocarbons in the fuel, a biocide to prevent microbial growth, a catalyst to provide better fuel economy and fewer emissions, and lubricity enhancers, to minimize wear.

Overall, the tests results showed a 3.2 percent (3.2%) reduction in main engine exhaust temperatures, a 4.9 percent (4.9%) increase in fuel economy, a 14.4 percent (14.4%) decrease in carbon monoxide emissions, a 5.4 percent (5.4%) decrease in carbon dioxide emissions, a 23.2 percent (23.2%) decrease in hydrocarbon emissions, and a visual reduction in engine and boiler deposits. *This test represents only three (3) months of use. With continued use, "FA-6048"will see an additional increase in fuel economy, continued decrease in emissions, including*

emissions which we did not test for, and further reduction in engine and boiler deposits for all ships using "FA-6048".

Accomplished the following during the test:

- **Improved combustion efficiency**
- **Improved heat transfer to the boilers**
- **Kept injector tips from atomizing orifices clean**
- **Allowed the burning of higher vanadium fuel oil without damage to exhaust valves**
- **Reduced corrosion, fouling, and acid emissions**
- **Reduced deposits in the turbo chargers for the main engines**
- **Reduced formation of slag deposits**
- **Reduced hydrocarbon and carbon monoxide and dioxide emissions**
- **Reduced soot, smoke and particulate emissions**
- **Reduced excess air requirements for proper combustion**
- **Reduced the number of burned exhaust gas valves**
- **Reduced combustion system maintenance**
- **Reduced back end scrubbing, grinding and maintenance on boilers**
- **Reduced stack temperatures**

ADDITIONAL COST SAVINGS ARE MANY:

- **Reduction in moisture before the fuel reaches the separators making it easier for the separators to separate the remaining moisture and contaminants. "FA-6048" provides a demulsifier that immediately starts to remove moisture from the fuel.**
- **Reduction in growth of microbes that clog filters and cause more frequent cleaning of filters. Provides a biocide that prevents microbial growth.**
- **Reduction in fuel costs from not using boiler #1. An unexpected result in the ability to use boiler #2 more frequently, even while in port, providing a direct savings of the fuel that would normally be burned off in boiler #1. The saved fuel can be used in the main and auxiliary engines.**
- **Elimination of the costs for having sludge removed from the ship as a toxic waste by an outside company.**

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- **Reduction in maintenance cost for boiler #1 and boiler #2. Due to less build-up, *maintenance will be reduced by at least 50 percent (50%) of the man-hours currently required, if not more.***

- **Elimination of the costs for other products currently used in the boilers such as soot sticks and other catalytic/sludge dispersant.**

- **Elimination of the costs for the sonic systems used to break-up the exhaust gases.**

- **Reduction in the costs for parts and labor for replacement of burnt valves, injectors and fuel pumps on both main and auxiliary engines.**

- **Reduction in the labor costs required to clean engine components during normal maintenance.**

- **Extension of preventative maintenance intervals for turbo chargers, exhaust boiler tubes, etc.**

- **Reduction in fuel costs for the main and auxiliary engines. The Carbon Mass Balance shows substantial gains and the pictures of the particulate filters show much improved burning of the fuel. "FA-6048" provides a polymerization inhibitor to prevent molecular "chaining" of the hydrocarbons in the fuel making it easier to burn.**