Fuel Performance Catalyst (FPC) Fuel Additive

Field Test Report
Brake Specific Fuel Consumption
Carbon Mass Balance
Exhaust Gas Emissions
Smoke Density

Prepared For: **Royal Caribbean International**

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May 14, 2012

Executive Summary

FPC is a fuel additive that has be thoroughly tested at independent laboratories all over the world. Multiple tests were performed on the *Navigator of the Seas* to determine if FPC would add value to Royal Caribbean's operations. Testing was conducted on two (DG1 and DG2) of the *Navigator's* six generators, which logged 331 (DG1) and 301 (DG2) operational hours with FPC treated fuel oil.

Brake Specific Fuel Consumption Results

Brake specific fuel oil consumption tests were conducted at two operating loads: 7 megawatts and 10 megawatts. All data was collected and logged using the *Navigator's* own systems. **The final results at 7MW showed an improvement of 2.2% and 2.5% for DG1 and DG2 respectively. Results at 10MW showed an improvement of 3.0% and 2.1% for DG1 and DG2 respectively.** The plotted results did not level off by the end of the testing, but the testing had to be concluded due to cabin availability for the testing engineer.

Carbon Mass Balance Results

A carbon mass balance analysis was performed using the gas emissions, which showed a 4.5% improvement in fuel economy. These results substantiate the results found with the brake specific fuel consumption testing.

Exhaust Gas Emissions Results

A portable gas analyzer was used to measure the reduction in exhaust emissions due to FPC use. **The results showed a 4.2% reduction for carbon dioxide (CO_2) emissions, a 16.0% reduction for carbon monoxide (CO) emissions, and a 20.4% reduction for unburned hydrocarbon (C_XH_Y) emissions.**

Smoke Density Results

A smoke density test was performed to measure the reduction in particulate matter (soot) emissions due to FPC use. **Results at 7MW showed a smoke density reduction of 31.0% and 25.7% for DG1 and DG2 respectively. Results at 10MW showed a smoke density reduction of 48.8% and 49.8% for DG1 and DG2 respectively.** The *Navigator's* Chief Engineer stated that he could visually see an improvement in the smoke density and thought the soot reduction would reduce maintenance costs for turbochargers, boiler after-coolers, and engine oil.

Business Case

Royal Caribbean's first quarterly report for 2012 reported fuel consumption of 342,000 metric-tons-per-quarter at a cost of $232 million-per-quarter. **A reduction of 3.5%, which is the average of the brake specific fuel consumption and carbon mass balance results obtained in this testing, would amount to a savings of 47,500 metric-tons-per-year or a gross savings of $32.2 million-per-year. With 217.9 million shares outstanding, the yearly savings represents 14.8¢ per-share.** At a cost of only $10.52 to treat a metric-ton of fuel oil, the net savings would be estimated at $17.8 million-per-year.

Greenhouse Gas Reduction and Carbon Footprint

Based on US EPA estimates, this fuel savings represents a carbon dioxide (CO_2) emissions reduction of 106,000 metric-tons-per-year[1]. Additionally, a 4.2% reduction in CO_2 emissions was also measured using fuel oil treated with FPC. This represents a CO_2 emissions savings of another 174,000 metric-tons-per-year. **It is estimated that Royal Caribbean would reduce their carbon footprint by 280,000 metric-tons-of-CO_2-per-year by using FPC.**

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[1] This analysis assumes a fuel oil density of 991.0 kilograms-per-cubic-meter and estimates reported by the US EPA at http://www.epa.gov/appdstar/pdf/brochure.pdf stating that consuming fuel oil emits 1081.42 pounds-of-CO_2-per-barrel.

Introduction

The FPC combustion catalysts, manufactured by FPC International and marketed by FPC Global Corp, have proven in laboratory and field trials to reduce fuel consumption in the range of 2% to 8% and to substantially reduce carbon emissions.

After meetings with technical personnel From Royal Caribbean International, it was agreed that fuel efficiency and emissions reduction tests would be conducted on the *Navigator of the Seas*. These tests would include

1. Brake specific fuel oil consumption tests
2. Carbon mass balance tests
3. Exhaust emissions tests for carbon dioxide (CO_2), carbon monoxide (CO), and unburned hydrocarbons (C_XH_Y)
4. Smoke density tests

The *Navigator of the Seas* is the fourth of Royal Caribbean International's five Voyager-class cruise ships and has been in service since late 2002. The *Navigator* is powered by six Wärtsilä 12V46C generators that can produce 12.6 MW each. The generators are designated DG1 through DG6.

The *Navigator* has seen less than 10 years of service, is meticulously maintained, and has high-efficiency Wärtsilä generators. For these reasons, the improvement from using the FPC additive was expected to be lower than other tests performed on older, under-maintained engines. FPC has been tested 14 times by independent laboratories on new or freshly-rebuilt engines. Based on these 14 tests, the average improvement from using FPC in like-new engines is 1.95% and is due to the catalytic effects of FPC.

FPC aids in combustion in two ways. First, FPC acts as a catalyst by lowering the activation energy needed to break down unburned products (including carbon monoxide, unburned hydrocarbons, and soot) of the combustion process. This catalytic effect improves combustion efficiency even for new engines. Second, FPC acts as a cleanser by removing carbon buildup in the engine. It does this not by dissolving the carbon buildup, but rather it turns the carbon buildup into a secondary energy source, which allows the engine to turn the available carbon into additional power. This cleansing effect requires an extended conditioning period to achieve full results.

The duration of the FPC conditioning period is proportional to the size of the engine being tested. For large power generators, like those used on the *Navigator*, the conditioning period averages close to 800 operational hours. Due to cabin limitations and required maintenance on the *Navigator's* generators it was only possible to run the testing for 331 operational hours on DG1 and 301 operational hours on DG2.

Brake Specific Fuel Oil Consumption Testing

Background

Brake specific fuel consumption (BSFC) is a metric that takes into account the amount of fuel required for a specific engine to generate a given amount of power. To compute BSFC, the rate of fuel consumption and the power being generated need to be measured. The BSFC is calculated by taking the ratio of these two measurements:

$$Brake\ Specific\ Fuel\ Consumption = \frac{Fuel\ Consumption\ Rate}{Power\ Generated}$$

The units of brake specific fuel consumption are grams-per-kilowatt-hour. The units of fuel consumption are grams-per-hour. The units of power generation are kilowatts.

Lower BSFC numbers translate into financial savings, so the basic premise behind the testing was to monitor the BSFC of the *Navigator's* generators and see if the value decreased while the fuel was treated with FPC.

Test Equipment

The *Navigator* was already instrumented to collect and log data for fuel consumption and power generation prior to testing. No additional sensors or transducers were needed to perform the brake specific fuel consumption testing. The *Navigator's* sensors were configured to feed data to a database and after a test on a generator was performed, the data was extracted into a Microsoft Excel spreadsheet for processing. Data integrity is guaranteed because the data acquisition system is automated and access to the data is only available via Royal Caribbean's personnel.

Fuel Consumption

The *Navigator* uses a VAF J5050 flow meter to monitor the fuel oil delivered to a recirculating loop that contains three generators (DG1, DG2, and DG3). The J5050 is a volumetric flow meter that reports the liters-per-hour delivered to the recirculating loop. A temperature sensor at the flow meter logs the temperature of the fuel going through the meter. The temperature of the fuel and the fuel density, as determined by laboratory analysis, were used to convert the fuel consumption from volumetric (liters-per-hour) measurements to gravimetric (kilograms-per-hour) measurements.

Per the J5050's specification sheet, the measuring accuracy is ±0.2% and the repeatability is better than ±0.05%. The sensor tracking the fuel temperature is a standard PT100 RTD sensor. The flow meter is shown in Figure 1.

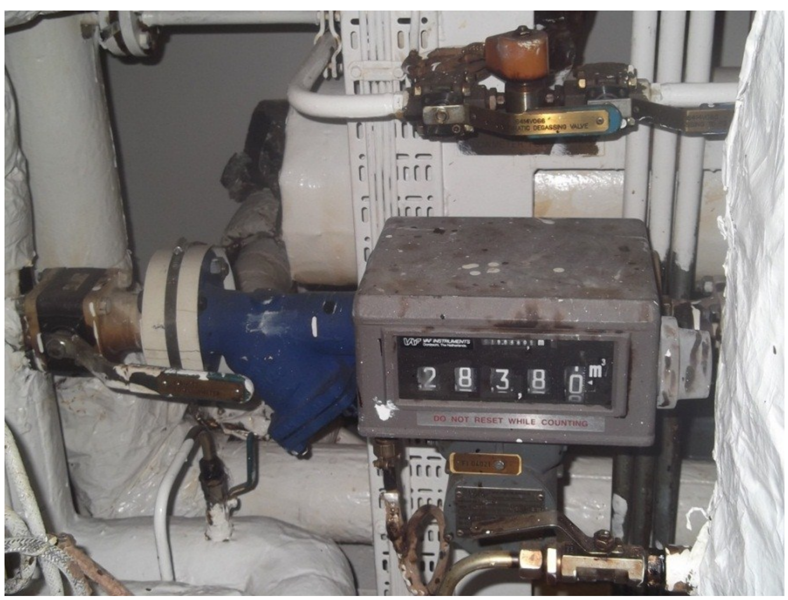


Figure 1 – VAF J5050 Flow Meter for Fuel Oil Consumption Measurements

Power Generation

The 11kV generated by a main generator pass through a potential transformer with a 100V secondary winding. The accuracy of the potential transformers is 0.5%.

The current transformers used have a 1% accuracy rating.

Feeder terminals from ABB are used which have an accuracy of 0.5%. Three Sineax P530 units are used as transducers for measuring the 3-phase voltage. The transducer for the current sensor is the Sineax I552. The Sineax equipment has an accuracy of 0.5% and converts the potential and current transformer signals into industry standard 4 to 20mA signals.

Figure 2 – Sineax Voltage and Current Measurement Transducers

The signal is then passed through an analog-to-digital converter before being recorded. The A/D converter has an accuracy of 0.1%.

Dosing Equipment

Figure 3 shows the dosing setup. An automatic dosing unit was used to inject the FPC catalyst into the pump suction line before the *Navigator's* fuel oil booster unit. The dosing unit used a pump to suck the FPC out of a 200 liter (55 gallon) drum and pump it through a 12 millimeter stainless steel tube to the injection point. An activated carbon scrubber was placed on the air vent of the drum. This was done for safety reasons. The dosing unit had a connection to the J5050 flow meter so that FPC could be injected into the fuel oil at the proper dosing ratio (1:10000).

The injection point is shown in Figure 4. A piece of tubing that connected the fuel oil line to a pressure gauge was retrofitted with a T-fitting for the FPC injection point. A ball valve and check valve (no return valve) were used at the injection point for safety.

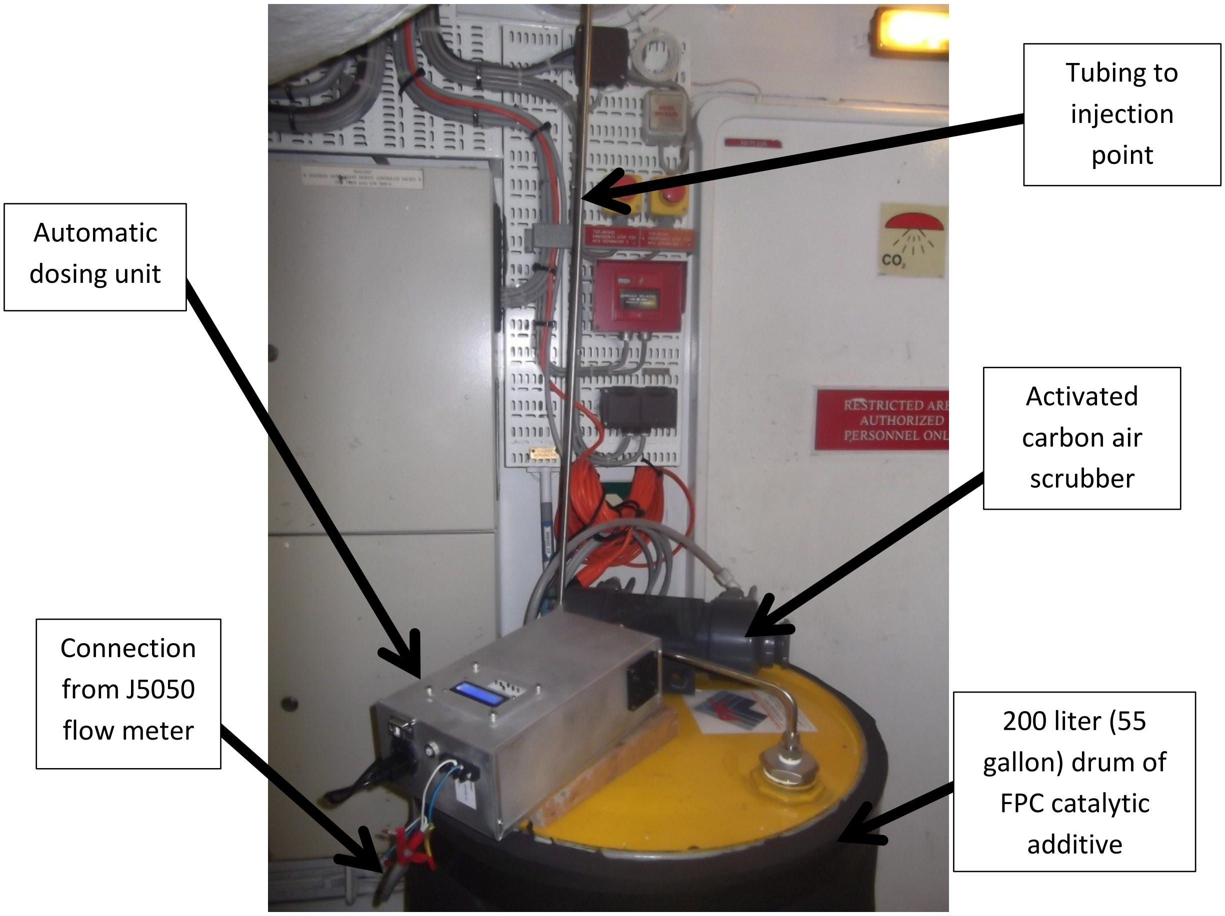


Figure 3 – FPC Dosing Installation

Figure 4 – FPC Injection Point

Test Procedure

The goal of the testing was to determine if FPC reduced the brake specific fuel consumption of the *Navigator's* main generators. Baseline results were collected for the engine efficiency before FPC had been added to the fuel. Then, results were collected while the fuel was being treated with FPC. These results were compared to the baseline data to see the effect of FPC on the fuel oil efficiency. Results were collected on two of the *Navigator's* generators, which are designated as DG1 and DG2.

Three generators (DG1, DG2, and DG3) are connected to the same booster unit, which has a single flow meter. Because of this each generator had to be tested independently. This meant that DG2 and DG3 had to be shut down while testing was being performed on DG1. Similarly, DG1 and DG3 had to be shut down while testing was being performed on DG2. This guaranteed that the fuel readings while DG1 was being tested only contained the effects of fuel consumption by DG1. If multiple generators were operational at the same time there would have been no way to tell how much fuel was delivered to each generator.

Data Processing

Results from the spreadsheet extracted from the *Navigator's* data acquisition database included the following data items:

- The power, in megawatts, of each of the *Navigator's* generators
- The fuel oil flow, in liters-per-hour, going into the booster unit feeding the three generators (DG1, DG2, and DG3).
- The temperature, in degrees Celsius, of the fuel oil at the flow meter.

The raw data was aggregated into a spreadsheet and the fuel flow data was corrected for temperature using ASTM D1250-80 Table 54B. This procedure takes into account the fuel oil density and temperature and provides a Volume Correction Factor (VCF) to normalize the volumetric flow to 15 degrees Celsius. This volumetric rate was then multiplied by the fuel oil's density as reported by the laboratory analysis results for the fuel oil. The result was a mass flow rate given in grams-per-hour. This was then used with the power generated result to compute the reported brake specific fuel consumption.

The laboratory fuel oil analysis results are available in Appendix 3. The bunkers on the *Navigator* are connected to a 168 cubic-meter settling tank, which in turn feeds a 168 cubic-meter service tank. Due to the size of the intermediate tanks and the fuel oil consumption rate of the *Navigator's* main generators it was estimated that it would take 4 days for the bunkered fuel to reach the engines. Consequently, the density value from the fuel oil analysis done on the fuel oil bunkered on April 3 was used initially. The analysis of the fuel oil bunkered on April 14 was used to analyze the data starting with and including the results from April 18. The results from the bunkering on April 26 were used starting with and including the data from April 30. The last fuel oil analysis, for fuel oil bunkered on May 3, was used on the data obtained on May 7 and afterwards. Although it is estimated that the fuel oil would take four days to travel from the bunkers to the engines, even if it took five days to reach the engines the final results given here would not change. This is because the final test was performed on May 1, which was five days after the previous bunkering.

Baseline Testing

Prior to treating the *Navigator's* fuel oil with FPC, baseline results were measured for the brake specific fuel consumption for the generators being tested with FPC. Two tests were performed on each generator to determine how repeatable the values for the BSFC would be and to confirm that an improvement in the range of 2% would be detectable. The results of the baseline testing are shown in Table 1.

Table 1 – Baseline Brake Specific Fuel Oil Consumption Test Results

Generator	Average Power Generated [MW]	Brake Specific Fuel Consumption [g/(kW*hr)]	Percentage Difference Between Tests	Baseline Result (Average BSFC of two tests) [g/(kW*hr)]
DG1	7.03	218.453	0.412%	218.904
	7.14	219.355		
DG1	9.87	213.515	0.090%	213.611
	9.92	213.707		
DG2	7.09	219.635	0.052%	219.692
	7.05	219.749		
DG2	9.86	210.758	0.021%	210.780
	9.94	210.802		

Table 1 shows that the percentage difference between the two baseline BSFC tests done on DG1 at 7MW is 0.412%. The DG1 test at 10MW shows a percentage difference of 0.090%. Based on this result it can be expected that the results of any treated test may be off by a similar amount.

The results from two baseline test on DG2 showed results that had better repeatability. At both 7MW and 10MW the results from two separate tests were within 0.052%. Based on this result it can be expected that the results of any treated test are quite close to actual value.

Treated Testing

Data was collected and processed as often as possible without putting strain on the *Navigator's* schedule and crew. Since testing one generator meant two other generators had to be shut down, it was not possible to test the system every day. The results are graphed in Figure 5.

Treatment of the fuel oil with FPC was stopped after the test conducted on May 1. This is because the injectors on DG1 were replaced on May 2, and this mechanical change would have an impact on the generator's efficiency and future brake specific fuel consumption (BSFC) results. There was no test performed on May 2. While testing could have continued on DG2, this possibility was abandoned because it was desired to perform a return-to-baseline test segment to see if ceasing FPC treatment would allow the generator efficiency to return to its baseline state. Further, due to cabin availability on the *Navigator*, the test engineer performing the tests onboard would only be able to stay until May 13.

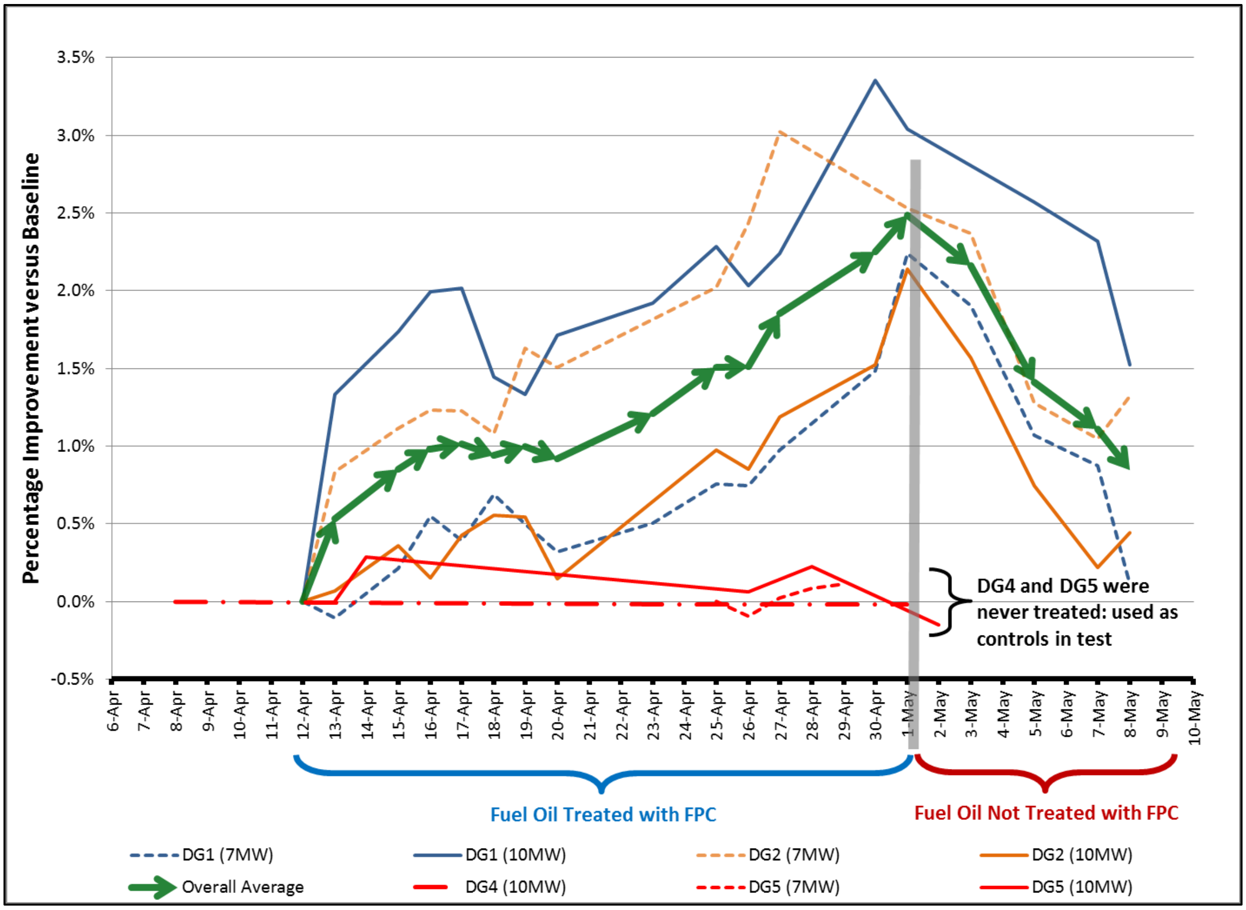


Figure 5 – Test Results During Treatment

While there is a certain amount of noise in the day-to-day readings, the "Overall Average" trend is apparent. The BSFC improved over the time of the FPC treatment. This slow gradual improvement is characteristic of FPC treatment. Figure 6 shows the results of FPC testing done by the world-renowned Southwest Research Institute (SwRI) on a new engine. These results from SwRI also show a slow increase in efficiency over a long period of operational hours. Also note that the generators on the *Navigator* are not run continuously, so the amount of operating time between the data points in Figure 5 is not a constant value.

After the testing was completed, data for the generators DG4, DG5, and DG6 were also analyzed. These generators were never treated with FPC. The logs from the *Navigator* were data-mined to see if these generators were ever run independently of the others. The logs showed that DG4 and DG5 were run independently at levels close to the 7MW and 10MW levels used of the tests. On most days, the generators were not run independently, so there are not many data points for these graphs. The BSFC results for the first day that did have results in the range of interest were used as the zero point for comparison with data from subsequent days. These results are also graphed in Figure 5. As expected, the efficiency of these generators stayed consistent over the duration of the testing. DG4 at 10MW had data on three days within the test period (8-April used as baseline, 24-April with -0.022% change from the baseline result from 8-April, and 1-May with -0.019% change from baseline). DG5 at 7MW had data on five days within the test period (25-April used as baseline, 26-April at -0.096%, 27-April at 0.025%, 28-April at 0.083%, and 29-April at 0.110%). DG5 at 10MW had data on five days within the test period (13-April used as baseline, 14-April at 0.285%, 26-April at 0.063%, 28-April at 0.222%, and 2-May at -0.149%)

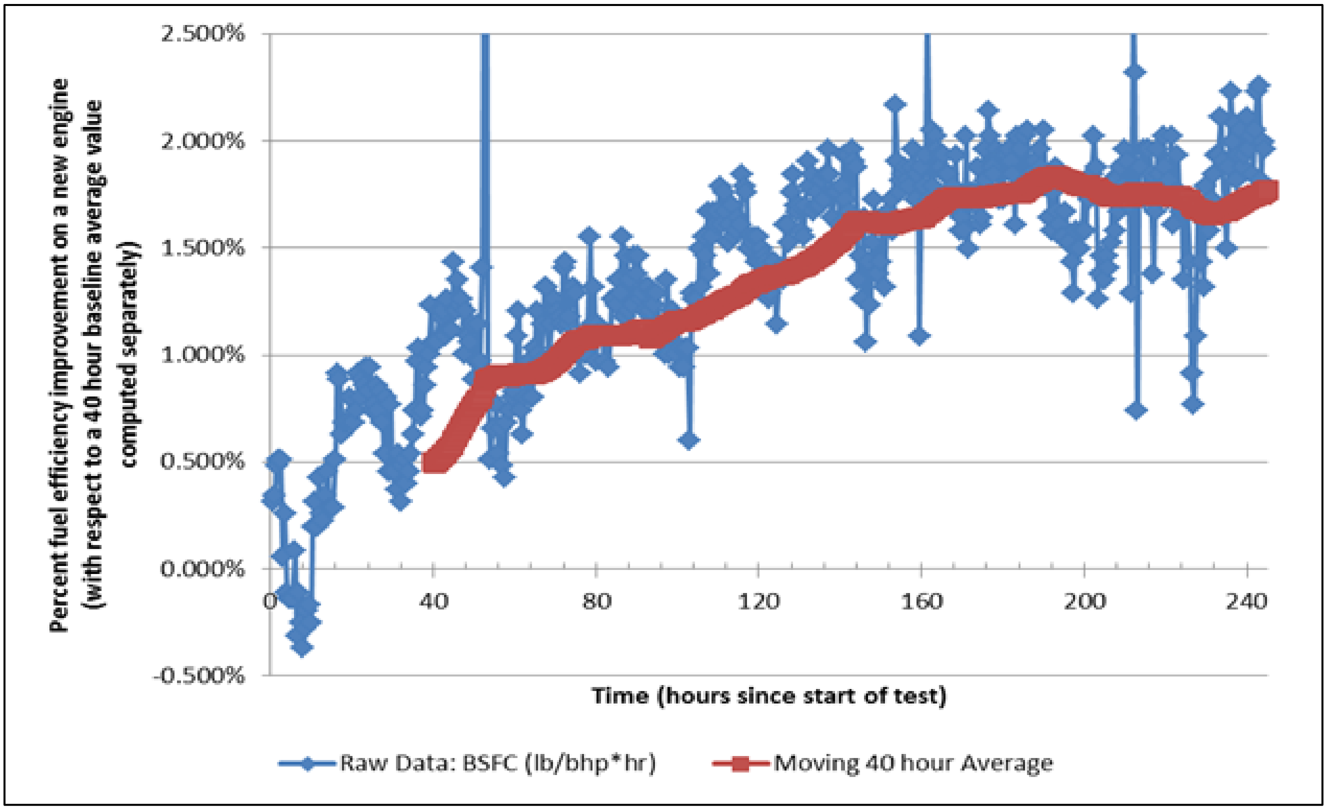


Figure 6 – Southwest Research Institute Test Results with FPC on a New Locomotive Engine

During the treated portion of the testing, DG1 obtained 331 operational hours and DG2 obtained 301 operational hours. The conditioning period required to achieve the maximum benefit from using FPC varies based on the size of the engine being treated: larger engines require longer conditioning periods. For generators the size of those on the *Navigator* the conditioning period is in the range of 800 hours. Due to the length of the conditioning period on the *Navigator* and because the results in Figure 5 did not appear to level off, it is believed that additional improvement could have been realized with a longer conditioning period.

Results of data obtained after FPC treatment was stopped show that the BSFC tended to go back toward the baseline values. Typically, once FPC treatment is stopped the BSFC values do not return all the way back to their baseline values. FPC has a cleansing effect on the engine. If treatment with FPC ceases, the engine will take a while to form new carbon deposits. The difference between the baseline results and results obtained after FPC treatment ceases represents the efficiency improvement due to engine cleansing. The reduction in efficiency after FPC treatment ceases represents the efficiency improvement due to the active catalytic ingredients in FPC.

Table 2 summarizes the final results, which are those taken from the testing done on May 1. The average of the improvements at 7MW is 2.376%. The average of the improvements at 10MW is 2.580%. These results are very close to what was expected based on the 14 previous tests done on new engines with FPC: 1.95%.

Table 2 – Final Results Summary (data from test done on May 1)

Generator	Average Power Generated during May 1 Testing [MW]	Average Brake Specific Fuel Consumption with FPC [g/(kW*hr)]	Baseline Brake Specific Fuel Oil Consumption [g/(kW*hr)]	Percentage Improvement versus Baseline
DG1	7.15	214.018	218.904	**2.232%**
	9.89	207.133	213.611	**3.033%**
DG2	7.03	214.154	219.692	**2.521%**
	9.88	206.295	210.780	**2.128%**

Carbon Mass Balance Results

The carbon mass balance (CMB) test procedure provides a means to calculate a fuel savings estimate based on emissions data. This procedure is given in the US EPA Federal Test Procedure (FTP) for vehicles and in Australian Standard AS2077-1982. The premise behind the CMB analysis is the principle of conservation of matter: all of the carbon being emitted from an engine must have come from the engine's fuel. By balancing the carbon in the exhaust, which is in the form of unburned hydrocarbons (C_XH_Y), carbon monoxide (CO), and carbon dioxide (CO_2), with the carbon content of the fuel an estimate for fuel consumption can be calculated.

The CMB worksheets are available in Appendix 1. Table 3 shows a summary of the CMB results.

Table 3 – Carbon Mass Balance Results Summary

Generator	Load	Percentage Improvement
DG1	7MW	**4.49%**
	10MW	**4.69%**
DG2	7MW	**4.38%**
	10MW	**4.28%**

The results of the carbon mass balance testing support the results of the brake specific fuel oil consumption test results. Both indicate that a fuel economy improvement was realized during the time of the FPC treatment.

Gas Emissions Results

An Enerac 700 gas analyzer was used to quantify emissions reductions obtained by using the FPC fuel catalyst. The Enerac 700 is a portable emissions analyzer that is compliant with US EPA and ISO standards. The analyzer's specifications are given in Table 4.

Table 4 – Enerac 700 Gas Analyzer Specifications

Emission	Sensing Range	Resolution	Accuracy	Sensor Technology
Oxygen (O_2)	0% – 25%	0.1%	± 0.2%	Electrochemical
Hydrocarbons (C_XH_Y)	0 – 30000ppm	1ppm	± 3%	NDIR
Carbon Monoxide (CO)	0 – 4500ppm	1ppm	± 2%	Dual Range SEM
Carbon Dioxide (CO_2)	0% – 20%	0.01%	± 3%	NDIR

To perform the emissions test the gas analyzer's probe was inserted into a small access port in the exhaust line as shown in Figure 7.

Figure 7 – Exhaust Stacks for DG1 (image at left) and DG2 (image at right)

The gas analysis results are available in the worksheets included in Appendix 1. Table 5 shows a summary of the emissions results. Each result in Table 5 represents the average of 10 sample readings from the exhaust stack.

Table 5 – Gas Emissions Results Summary

Emission	Generator	Load	Baseline	Treated	Percentage Change
Carbon Monoxide (CO)	DG1	7MW	1841.7ppm	1561.3ppm	**-15.2%**
		10MW	1543.1ppm	1215.4ppm	**-21.2%**
	DG2	7MW	1634.9ppm	1399.0ppm	**-14.4%**
		10MW	1414.3ppm	1225.4ppm	**-13.4%**
Carbon Dioxide (CO_2)	DG1	7MW	5.72%	5.50%	**-3.8%**
		10MW	5.84%	5.58%	**-4.5%**
	DG2	7MW	5.50%	5.28%	**-4.0%**
		10MW	5.90%	5.63%	**-4.6%**
Hydrocarbons (C_XH_Y)	DG1	7MW	288.3ppm	209.7ppm	**-27.3%**
		10MW	166.8ppm	119.5ppm	**-28.4%**
	DG2	7MW	278.7ppm	246.8ppm	**-11.4%**
		10MW	189.7ppm	162.4ppm	**-14.4%**

Note: a negative percentage change represents a reduction in emissions.

Smoke Density Results

A smoke density test was performed on the exhaust gases from DG1 and DG2 during the baseline portion of the test and again on May 1 at the conclusion of the treatment with the FPC catalyst. This was done to measure the improvement FPC usage would have on soot and particulate matter emissions. This testing was performed in accordance with ASTM D2156-94. Appendix 2 contains the digitized test specimens and smoke density standard.

Direct photometric evaluation techniques were used to eliminate human factors and subjectivity in analyzing the smoke density results. The test samples obtained were digitally scanned along with a smoke density scale standard conforming to ASTM D2156-63T. The scale on the standard was then digitally analyzed to determine the average gray values for each spot. The result of this analysis is in Table 6.

Table 6 – Smoke Density Photometric Analysis of ASTM D2156-63T Standard

Smoke Density Value	Gray Value of Standard (45x45 Pixel Average)
9	72
8	94
7	117
6	138
5	160
4	180
3	199
2	216
1	237
0	251

The resulting photometric analysis was then curve fitted using a least squares regression technique to determine the best fitting cubic function to the data from the smoke density standard. The cubic function found is:

$$SDV = -1.763308 \times 10^{-7}\, GV^3 + 3.779100 \times 10^{-5}\, GV^2 - 0.046975\, GV + 12.245600$$

where SDV is the smoke density value and GV is the gray value. Figure 8 shows how the obtained cubic function compares with the data obtained from the standard.

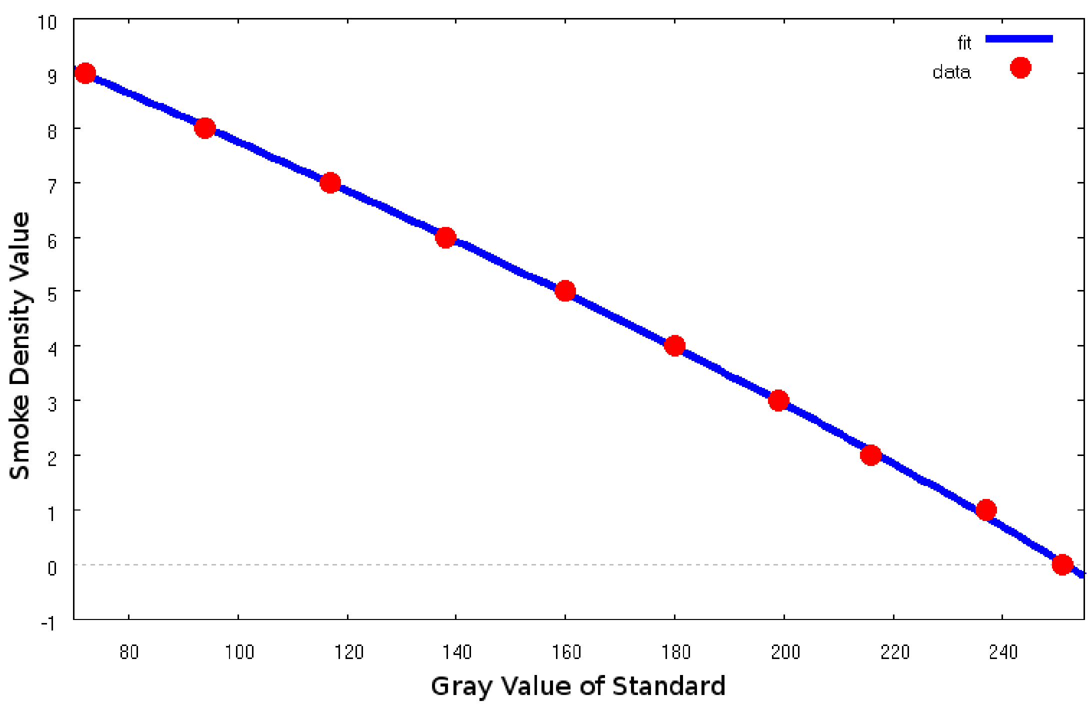


Figure 8 – Curve Fitting Results on Smoke Density Standard

The smoke density samples taken from DG1 and DG2 were then digitally analyzed. The smoke density values were then calculated using the equation from the curve fitting performed on the standard. The results are given in Table 7. The gray values reported in Table 7 represent a 15x15 pixel average from the center of the image of the test sample.

Table 7 – Smoke Density Test Results

Generator	Load	Baseline Result (Tested on April 9)		Treated Result (Tested on May 1)		Percentage Change
		Gray Value	Smoke Density Value	Gray Value	Smoke Density Value	
DG1	7 MW	154	5.26	187	3.63	**-31.0%**
	10 MW	137	6.07	197	3.11	**-48.8%**
DG2	7 MW	159	5.02	185	3.73	**-25.7%**
	10 MW	132	6.30	196	3.16	**-49.8%**

In addition to the above results, the *Navigator's* Chief Engineer, M. Mehta, stated that he was able to notice a visual decrease in the darkness of the smoke coming out from the stacks compared to previous observations made by him with untreated engines.

Maintenance Benefits

In addition to the benefits verified by this testing, FPC has been shown to:

- **Extend Engine Life**

  FPC removes accumulated combustion chamber carbon and prevents the formation of new deposits, decreasing wear and fouling. By lowering the activation energy needed to further break down the unburned products of combustion, FPC causes these products to be consumed during the combustion process. This reduces carbon deposits on the injectors, piston face, rings and valves thereby extending injector life and reducing engine wear dramatically.

- **Reduce Maintenance and Downtime**

  Tests have shown that oil filters last longer, engine adjustments and overhauls are decreased or overhauls periods extended, and oil change intervals are extended. Additionally, the reduction in soot and carbon deposits will reduce maintenance costs for gas boiler exhausts and turbochargers.

- **Reduce Oil Contaminants and Oil Consumption**

  Oil is ultimately contaminated with soot and carbon because of cylinder washing or blow-by. Oil analysis on heavy duty engines conducted over an extended period of time have shown a substantial reduction in oil contaminants when using fuel treated with FPC.

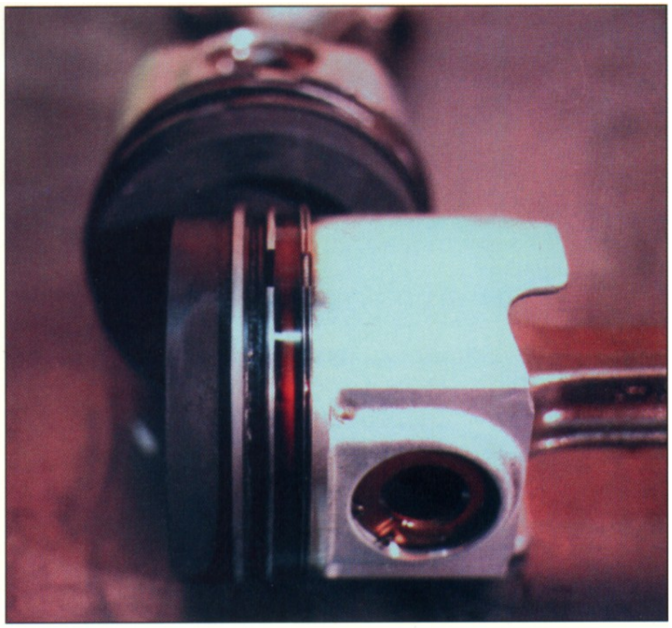


Figure 9 – Pistons after 13,000 operational hours with FPC

The pistons in Figure 9 were removed from a 3408 Caterpillar engine after 13,000 hours of service. There was only light carbon soot on the piston faces. The rings were carbon free and moved without restriction.

Iron wear rate reduction between 18.1% and 46.8% were obtained from oil analysis data after the use of FPC and expressed in ppm-per-hour. This represents a rate of wear that is meaningful in terms of overall engine lift. The contribution to abrasive wear by soot in the lubrication oil and hard carbon deposits on rubbing surfaces is the factor of interest here. The results of iron wear reductions for BHP Billiton Norwich Park Coal Mine in Australia from eight Caterpillar 777D engines are summarized in Table 8.

Table 8 – Iron Wear Rate Test Results from Oil Analysis

Unit Number	Wear Rate [ppm iron/hour]		Percentage Change
	Untreated	FPC Treated	
TRD 91	0.340	0.205	**-39.6%**
TRD 93	0.334	0.224	**-32.9%**
TRD 151	0.166	0.135	**-18.7%**
TRD 1772	0.079	0.042	**-46.8%**
TRD 1773	0.106	0.058	**-45.7%**
TRD 2250	0.327	0.194	**-40.7%**
TRD 3569	0.103	0.081	**-21.4%**
TRD 3630	0.035	0.029	**-18.1%**
Average			**-33.0%**

Figure 10 – Images from BHP Billiton Norwich Park Coal Mine

Figure 11 – Caterpillar 3412 Pistons after 14,000 operating hours using FPC

Figure 12 shows a Caterpillar 3412 piston after 14,000 operational hours. Notice the piston has been wiped clean with a soft workshop rag.

Figure 12 – MTU Pistons after 23,000 operating hours using FPC

Figure 12 shows a MTU piston and liner following 23,000 hours running on FPC treated fuel. Wear and carbon deposits were so minimal that engine parts were reusable. Liner cross hatching is still visible indicating little wear.

Conclusions

Multiple tests were done to confirm the effectiveness of the FPC fuel additive in Royal Caribbean's *Navigator of the Seas* vessel. Each test demonstrated that FPC would provide benefits. Fuel savings were confirmed using a brake specific fuel oil consumption test using Royal Caribbean's own instruments. These results were corroborated with results obtained by a carbon mass balance procedure that analyzed the gas emissions from the *Navigator's* engine exhaust ports. Emissions testing also found reductions in carbon dioxide (CO_2), carbon monoxide (CO), and unburned hydrocarbons (C_XH_Y). Furthermore, a smoke density test demonstrated reductions in particulate matter in the engine exhaust. These results are in line with testing done using FPC in well-maintained and like-new engines at independent laboratories in the United States, Canada, India, and Australia.

In addition to the benefits confirmed by this testing, Royal Caribbean can expect to see savings in the form of reduced maintenance costs as well. These will be realized by extending the time between overhaul cycles and by the reduction of the amount of time required for overhauls.

If the results from this testing are extrapolated against Royal Caribbean's total fuel usage, the savings would amount to over $32.2 million in gross fuel savings per year. In addition, Royal Caribbean would reduce their carbon footprint by almost 280,000 metric-tons-of-CO_2-emissions-per-year.

Appendix 1

Gas Emissions Data and Carbon Mass Balance Worksheets

Each of the following worksheets contains a separate column for emissions readings for carbon monoxide (CO), unburned hydrocarbons (C_XH_Y), and carbon dioxide (CO_2).

Ten samples were averaged to obtain the results given in the report. Each of those ten samples is given in the worksheets below.

The baseline and treated results are compared at the bottom of the page for the treated results and a performance factor (PF) is calculated and provided, which is proportional to fuel efficiency. This performance factor is the result of the carbon mass balance analysis.

Generator DG1 – 7MW – Baseline Results

FPC GLOBAL CORP.			**CARBON MASS BALANCE TEST RESULTS**					
Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Date:***	4/9/2012	
Test Portion:	Untreated	***Stack Diam.***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs***		**Fuel:**	***IFO-380***		
Equipment Type:	**6X12V46C**	***ID #:***	DG-1 -7MW		***Baro***	30.00	
Fuel Sp. Gravity(SG)	.990	***Temp:***	59				
					Time:	19:10	
P. Load (MW)	**Exh Temp(F)**	**Pv (Inch-Hg)**	**CO (PPM)**	**HC (PPM)**	**CO2 (%)**	**O2 (%)**	
7	639	0.21	1579	251	5.70	13.2	
7	642	0.21	1736	266	5.70	13.1	
7	639	0.22	1843	268	5.70	13.2	
7	641	0.22	1849	281	5.70	13.2	
7	642	0.22	1869	286	5.70	13.1	
7	643	0.2	1886	293	5.7	13.2	
7	644	0.21	1894	297	5.7	13.1	
7	643	0.22	1901	307	5.7	13.1	
7	640	0.22	1907	314	5.8	13.1	
7	638	0.23	1953	320	5.8	13.1	
7	**641.100**	**.216**	**1841.700**	**288.300**	**5.720**	**13.140**	Mean
0	**2.025**	**.008**	**108.449**	**22.291**	**.042**	**.052**	Std Dev
VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mwt1**	**pf1**	**PF1**	
2.88E-04	0.0018417	.057	.131	29.4454128	109,596	293	
Denominator pf1	Exh Temp ^{o}K	(d/2)^2*3.14/144	Denominator			F	
0.832774413	1101.10	153.86	0.036100263	5.983335849	2.446085822	412560.0929	

Generator DG1 – 7MW – Treated Results

Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Test Date:***	5/1/2012	
Test Portion:	Treated	***Stack Diam:***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs:***	337				
Equipment Type	**6X12V46C**	***ID #:***	DG1 - 7MW		***Baro:***	29.94	
Fuel Sp. Gravity:	.990	***Temp:***	59				
SG Corr Factor:	.999				***Time:***	21:45	

P. Load (MW)	Exh Temp(F)	Pv (Inch-Hg)	CO (PPM)	HC (PPM)	CO2 (%)	O2 (%)	
7	640	0.21	1610	172	5.5	13.3	
7	640	0.21	1608	173	5.5	13.3	
7	640	0.22	1585	174	5.5	13.3	
7	640	0.21	1564	178	5.5	13.3	
7	641	0.22	1552	180	5.5	13.3	
7	641	0.21	1557	181	5.5	13.3	
7	641	0.23	1540	182	5.5	13.3	
7	643	0.22	1537	286	5.5	13.3	
7	643	0.21	1538	281	5.5	13.3	
7	643	0.22	1522	290	5.5	13.3	
7.000	**641.200**	**.216**	**1561.300**	**209.700**	**5.500**	**13.300**	Mean
0	**1.317**	**.007**	**30.474**	**52.572**	**.000**	**.000**	Std Dev
VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mtw2**	**pf2**	**PF2**	
2.10E-04	0.0015613	.055	.133	29.4153552	114,706	306	
Denominator pf1	Exh Temp °K	(d/2)^2*3.14/144	Denominator			F	
0.794863257	1101.20	153.86	0.036024791	5.995870987	2.448646767	412992.0252	
Performance factor adjusted for fuel density:			306	****% Change PF=**			**4.49**

*** A positive change in PF equates to a reduction in fuel consumption.*

Generator DG1 – 10MW – Baseline Results

FPC GLOBAL CORP.			**CARBON MASS BALANCE TEST RESULTS**				
Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Date:***	4/9/2012	
Test Portion:	Untreated	***Stack Diam.***	168	Inches			
Engine Type:	**Wartsila**	***Mile/Hrs***		**Fuel:**	***IFO-380***		
Equipment Type:	**6X12V46C**	***ID #:***	DG-1 -10MW		***Baro***	29.97	
Fuel Sp. Gravity(SG)	.990	***Temp:***	59				
					Time:	20:40	

P. Load (MW)	Exh Temp(F)	Pv (Inch-Hg)	CO (PPM)	HC (PPM)	CO2 (%)	O2 (%)	
10	595	0.17	1289	105	5.90	12.9	
10	602	0.17	1438	119	5.90	12.9	
10	601	0.17	1534	134	5.80	12.9	
10	604	0.16	1550	144	5.90	12.9	
10	602	0.17	1572	149	5.80	12.9	
10	604	0.15	1584	159	5.8	12.9	
10	601	0.16	1598	168	5.9	12.9	
10	605	0.17	1606	180	5.8	12.9	
10	604	0.17	1607	220	5.8	12.9	
10	605	0.18	1653	290	5.8	12.9	
10	**602.300**	**.167**	**1543.100**	**166.800**	**5.840**	**12.900**	Mean
0	**2.983**	**.008**	**106.136**	**54.018**	**.052**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mwt1	pf1	PF1
1.67E-04	0.0015431	.058	.129	29.4530688	108,688	324

Denominator pf1	Exh Temp °K	(d/2)^2*3.14/144	Denominator			F
0.839948859	1062.30	153.86	0.037381389	4.46746369	2.113637549	356488.9244

Generator DG1 – 10MW – Treated Results

Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Test Date:***	5/1/2012	
Test Portion:	Treated	***Stack Diam:***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs:***	337				
Equipment Type	**6X12V46C**	***ID #:***	DG1-10 MW		***Baro:***	29.94	
Fuel Sp. Gravity:	.990	***Temp:***	59				
SG Corr Factor:	.999				***Time:***	21:08	

P. Load (MW)	Exh Temp(F)	Pv (Inch-Hg)	CO (PPM)	HC (PPM)	CO2 (%)	O2 (%)	
10	599	0.17	1151	103	5.5	13.3	
10	599	0.17	1211	109	5.5	13.3	
10	599	0.16	1218	111	5.6	13.3	
10	600	0.17	1219	119	5.6	13.2	
10	600	0.16	1220	122	5.6	13.2	
10	600	0.15	1221	125	5.6	13.2	
10	600	0.18	1225	127	5.6	13.2	
10	600	0.18	1230	131	5.6	13.2	
10	601	0.17	1224	134	5.6	13.2	
10	601	0.17	1235	136	5.6	13.2	
10.000	**599.900**	**.168**	**1215.400**	**121.700**	**5.580**	**13.230**	Mean
0	**.738**	**.009**	**23.576**	**11.126**	**.042**	**.048**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2	
1.22E-04	0.0012154	.056	.132	29.4239472	114,389	339	
Denominator pf1	Exh Temp °K	(d/2)^2*3.14/144	Denominator			F	
0.797298706	1059.90	153.86	0.037428531	4.488554467	2.118620888	357329.421	
Performance factor adjusted for fuel density:			339	****% Change PF=**			**4.69**
		***** A positive change in PF equates to a reduction in fuel consumption.***					

Generator DG2 – 7MW – Baseline Results

FPC GLOBAL CORP.			CARBON MASS BALANCE TEST RESULTS				
Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Date:***	4/9/2012	
Test Portion:	Untreated	***Stack Diam.***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs***		**Fuel:**	***IFO-380***		
Equipment Type:	**6X12V46C**	***ID #:***	DG2 -7MW		***Baro***	29.97	
Fuel Sp. Gravity(SG)	.990	***Temp:***	59				
					Time:	21:19	
P. Load (MW)	**Exh Temp(F)**	**Pv (Inch-Hg)**	**CO (PPM)**	**HC (PPM)**	**CO2 (%)**	**O2 (%)**	
7	635	0.20	1683	244	5.40	12.8	
7	636	0.22	1625	250	5.50	12.8	
7	636	0.22	1618	258	5.40	12.8	
7	636	0.21	1620	267	5.50	12.8	
7	636	0.22	1618	274	5.50	12.8	
7	636	0.21	1626	284	5.5	12.9	
7	636	0.21	1638	291	5.5	12.8	
7	636	0.22	1626	297	5.5	12.8	
7	636	0.23	1645	303	5.6	12.8	
7	636	0.22	1650	319	5.6	12.8	
7	**635.900**	**.216**	**1634.900**	**278.700**	**5.500**	**12.810**	Mean
0	**.316**	**.008**	**20.284**	**24.368**	**.067**	**.032**	Std Dev
VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mwt1**	**pf1**	**PF1**	
2.79E-04	0.0016349	.055	.128	29.3968592	114,052	304	
Denominator pf1	Exh Temp ^{o}K	(d/2)^2*3.14/144	Denominator			F	
0.798921561	1095.90	153.86	0.036235286	5.961040286	2.441524173	411790.7191	

Generator DG2 – 7MW – Treated Results

Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Test Date:***	5/1/2012	
Test Portion:	Treated	***Stack Diam:***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs:***	327				
Equipment Type	**6X12V46C**	***ID #:***	DG2 - 7MW		***Baro:***	29.94	
Fuel Sp. Gravity:	.990	***Temp:***	59				
SG Corr Factor:	.999				***Time:***	23:35	

P. Load (MW)	Exh Temp(F)	Pv (Inch-Hg)	CO (PPM)	HC (PPM)	CO2 (%)	O2 (%)	
7	634	0.20	1353	142	5.2	13.3	
7	634	0.22	1369	150	5.3	13.3	
7	634	0.21	1388	155	5.3	13.3	
7	634	0.22	1400	269	5.3	13.3	
7	635	0.22	1405	273	5.2	13.3	
7	635	0.22	1414	280	5.3	13.3	
7	635	0.23	1416	295	5.3	13.3	
7	635	0.22	1416	298	5.3	13.3	
7	636	0.20	1414	301	5.3	13.3	
7	636	0.22	1415	305	5.3	13.3	
7.000	**634.800**	**.216**	**1399.000**	**246.800**	**5.280**	**13.300**	Mean
0	**.789**	**.010**	**22.256**	**68.582**	**.042**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2	
2.47E-04	0.001399	.053	.133	29.3807488	119,249	317	
Denominator pf1	Exh Temp °K	(d/2)^2*3.14/144	Denominator			F	
0.76368331	1094.80	153.86	0.036235385	5.961023935	2.441520824	411790.1543	
Performance factor adjusted for fuel density:			317	****% Change PF=**			**4.38**

***** A positive change in PF equates to a reduction in fuel consumption.***

Generator DG2 – 10MW – Baseline Result

FPC GLOBAL CORP.			CARBON MASS BALANCE TEST RESULTS				
Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Date:***	4/9/2012	
Test Portion:	Untreated	***Stack Diam.***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs***		**Fuel:**	***IFO-380***		
Equipment Type:	**6X12V46C**	***ID #:***	DG-2 -10MW		***Baro***	29.97	
Fuel Sp. Gravity(SG)	.990	***Temp:***	59				
					Time:	20:30	
P. Load (MW)	**Exh Temp(F)**	**Pv (Inch-Hg)**	**CO (PPM)**	**HC (PPM)**	**CO2 (%)**	**O2 (%)**	
10	610	0.18	1437	163	5.80	12.7	
10	610	0.16	1390	172	5.90	12.7	
10	610	0.17	1385	178	5.90	12.7	
10	610	0.16	1371	181	5.90	12.6	
10	610	0.17	1370	184	5.90	12.7	
10	610	0.16	1353	189	5.90	12.7	
10	609	0.17	1355	197	5.90	12.6	
10	610	0.17	1410	206	5.90	12.7	
10	610	0.17	1524	210	6.00	12.7	
10	610	0.16	1548	217	5.90	12.6	
10	**609.900**	**.167**	**1414.300**	**189.700**	**5.900**	**12.670**	Mean
0	**.316**	**.007**	**69.125**	**17.474**	**.047**	**.048**	Std Dev
VFHC	**VFCO**	**VFCO2**	**VFO2**	**Mwt1**	**pf1**	**PF1**	
1.90E-04	0.0014143	.059	.127	29.4538352	107,723	322	
Denominator pf1	Exh Temp °K	(d/2)^2*3.14/144	Denominator			F	
0.847501427	1069.90	153.86	0.037115852	4.499425211	2.12118486	357761.8639	

Generator DG2 – 10MW – Treated Result

Company Name:	Royal Caribbean	***Location:***	Navigator Ship		***Test Date:***	5/1/2012	
Test Portion:	Treated	***Stack Diam:***	168	Inches			
Engine Type:	Wartsila	***Mile/Hrs:***	327				
Equipment Type	**6X12V46C**	***ID #:***	DG2-10 MW		***Baro:***	29.94	
Fuel Sp. Gravity:	.990	***Temp:***	59				
SG Corr Factor:	.999				***Time:***	22:45	

P. Load (MW)	Exh Temp(F)	Pv (Inch-Hg)	CO (PPM)	HC (PPM)	CO2 (%)	O2 (%)	
10	613	0.18	1162	140	5.6	13.1	
10	612	0.16	1220	144	5.6	13.1	
10	612	0.17	1226	152	5.6	13.1	
10	611	0.18	1228	161	5.6	13.1	
10	611	0.16	1231	167	5.6	13.1	
10	610	0.15	1232	171	5.6	13.1	
10	608	0.17	1234	174	5.6	13.1	
10	607	0.18	1238	170	5.7	13.1	
10	607	0.17	1236	172	5.7	13.1	
10	607	0.17	1247	173	5.7	13.1	
10.000	**609.800**	**.169**	**1225.400**	**162.400**	**5.630**	**13.100**	Mean
0	**2.348**	**.010**	**23.434**	**12.660**	**.048**	**.000**	Std Dev

VFHC	VFCO	VFCO2	VFO2	Mtw2	pf2	PF2	
1.62E-04	0.0012254	.056	.131	29.4273984	113,143	336	
Denominator pf1	Exh Temp °K	(d/2)^2*3.14/144	Denominator			F	
0.806173406	1069.80	153.86	0.037082165	4.557446969	2.134817784	360061.211	
Performance factor adjusted for fuel density:			336	****% Change PF=**			**4.28**

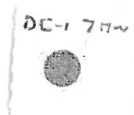
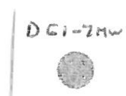
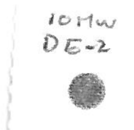
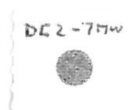
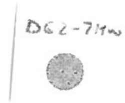
***** A positive change in PF equates to a reduction in fuel consumption.***

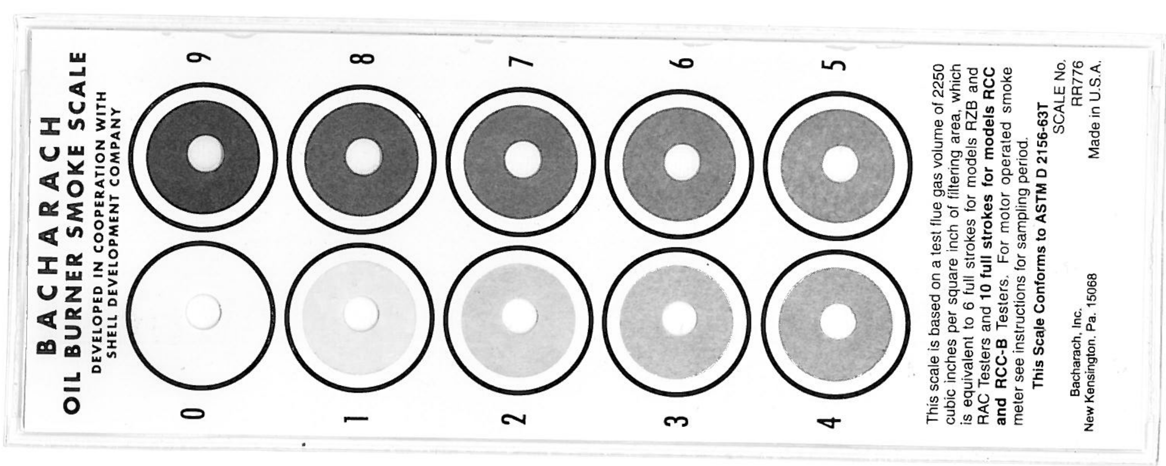
Appendix 2

Smoke Density Test Specimens and Smoke Density Standard

BACHARACH TRUE SPOT SMOKE METER FILTER TEST RESULTS FOR NAVIGATOR OF THE SEAS

This testing was done in per ASTM D2156-94

ENGINE #/Load	Baseline 4/9/2012	Bacharach Smoke Scale No.	Treated 5/1/2012	Bacharach Smoke Scale No.
DG1 / 10 MW		6.1		3.1
DG1/ 7 MW		5.3		3.6
DG2 / 10 MW		6.3		3.2
DG2 / 7 MW		5.0		3.7



Appendix 3

Laboratory Results of Fuel Oil Analysis

Bunkering on 3-April-2012

NAVIGATOR OF THE SEAS, FUEL ANALYSIS REPORT, ST. MAARTEN, 03-APR-2012

GT700 to: SZielonka 04/06/2012 04:38 PM

Cc: tmurrell, jhalvorsen, stiliyan.dimov, nv_chiefengineer, fuelorders, JVainio, nv_chiefengineerjr

Please respond to GT700

To: ROYAL CARIBBEAN INTERNATIONAL
Attn: Mr Simon Zielonka
Attn: Ms Tracy Murrell
Attn: Mr Jan-Erik Halvorsen
Attn: Mr Paul Litvinov, Director, Global Fuel Sourcing
Attn: Mr Juha Vainio

Cc: WARTSILA NA INC
Attn: Mr Stiliyan Dimov, Contract Manager

Cc: The Master Of 'NAVIGATOR OF THE SEAS'
Attn: Chief Engineer
Attn: Junior Chief Engineer

DNV Petroleum Services - Fuel Analysis Report dated: 06-Apr-2012

Vessel: NAVIGATOR OF THE SEAS (9227508)

Sample Number	HOU1207720
Product Type	(HFO)
Bunker Port	ST. MAARTEN
Bunker Date	03-Apr-2012
Sampling Point	SHIP MANIFOLD
Sampling Method	CONTINUOUS DRIP
Sent From	ST.MAARTEN
Date Sent	04-Apr-2012
Arrived at Lab	05-Apr-2012
Supplier	NUSTAR
Loaded From	STATIA FACTOR
Quantity per C.Eng.	1700

Seal Data DNVPS, SEAL INTACT, 6261335

Related Samples	
Supplier	6261336
Ship	6215730
Ship (DNVPS MARPOL)	4091446

Receipt Data	Unit	
Source Of Data*		Ch.Eng
Density @ 15°C	kg/m³	988.2
Viscosity @ 50°C	mm²/s	345.2
Sulfur	% m/m	2.60

*Please include a copy of the Bunker Delivery Note (BDN).

Test Parameter	Unit	Result	RMG380

Density @ 15°C	kg/m³	989.7	991.0
Viscosity @ 50°C	mm²/s	367.5	380.0
Water	% V/V	0.2	0.5
Micro Carbon Residue	% m/m	13	18
Sulfur	% m/m	2.60	3.50
Total Sediment Potential	% m/m	0.02	0.10
Ash	% m/m	0.06	0.15
Vanadium	mg/kg	189	300
Sodium	mg/kg	45	
Aluminium	mg/kg	5	
Silicon	mg/kg	7	
Iron	mg/kg	11	
Nickel	mg/kg	60	
Calcium	mg/kg	7	
Magnesium	mg/kg	LT 1	
Lead	mg/kg	LT 1	
Zinc	mg/kg	1	
Phosphorus	mg/kg	LT 1	
Potassium	mg/kg	LT 1	
Pour Point	°C	LT 24	30
Flash Point	°C	GT 70	60

Calculated Values

Aluminium + Silicon	mg/kg	12	80
Net Specific Energy	MJ/kg	40.29	
CCAI (Ignition Quality)	-	851	

Note:
LT means Less Than, GT means Greater Than

Specification Comparison :

Results compared with amended ISO 8217:2005 specification RMG380, table 2. Based on this sample the specification is met.

Operational Advice

Approximate fuel temperatures:

Injection:
145°C for 10 mm²/s
125°C for 15 mm²/s
115°C for 20 mm²/s
110°C for 25 mm²/s

Transfer :
45°C

Best Regards,
On behalf of DNV Petroleum Services Pte Ltd
Christian Ryder
Assistant Technical Advisor

End of Report for NAVIGATOR OF THE SEAS

Reference to part(s) of this report which may lead to misinterpretation is prohibited.

Bunkering on 14-April-2012

NAVIGATOR OF THE SEAS, FUEL ANALYSIS REPORT, FORT LAUDERDALE, 14-APR-2012

GT700 to: SZielonka 04/18/2012 07:28 PM

Cc: tmurrell, jhalvorsen, stiliyan.dimov, nv_chiefengineer, fuelorders, JVainio, nv_chiefengineerjr

Please respond to GT700

History: This message has been forwarded.

To: ROYAL CARIBBEAN INTERNATIONAL
Attn: Mr Simon Zielonka
Attn: Ms Tracy Murrell
Attn: Mr Jan-Erik Halvorsen
Attn: Mr Paul Litvinov, Director, Global Fuel Sourcing
Attn: Mr Juha Vainio

Cc: WARTSILA NA INC
Attn: Mr Stiliyan Dimov, Contract Manager

Cc: The Master Of 'NAVIGATOR OF THE SEAS'
Attn: Chief Engineer
Attn: Junior Chief Engineer

DNV Petroleum Services - Fuel Analysis Report dated: 18-Apr-2012

Vessel: NAVIGATOR OF THE SEAS (9227508)

Sample Number	HOU1208645
Product Type	(HFO)
Bunker Port	FORT LAUDERDALE
Bunker Date	14-Apr-2012
Sampling Point	SHIP MANIFOLD
Sampling Method	CONTINUOUS DRIP
Sent From	FORT LAUDERDALE, FL
Date Sent	16-Apr-2012
Arrived at Lab	17-Apr-2012
Supplier	TRANSMONT
Loaded From	401
Quantity per C.Eng.	1400

Seal Data DNVPS, SEAL INTACT, 5652705

Related Samples	
Supplier	5652706
Ship	6058519
Ship (DNVPS MARPOL)	6058520

Receipt Data	Unit	
Source Of Data*		Ch.Eng
Density @ 15°C	kg/m^3	990.3
Viscosity @ 50°C	mm^2/s	356.0
Sulfur	% m/m	3.44

*Please include a copy of the Bunker Delivery Note (BDN).

Test Parameter Unit Result RMG380

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Density @ 15°C	kg/m³	990.4	991.0
Viscosity @ 50°C	mm²/s	355.6	380.0
Water	% V/V	0.1	0.5
Micro Carbon Residue	% m/m	14	18
Sulfur	% m/m	3.34	3.50
Total Sediment Potential	% m/m	LT 0.01	0.10
Ash	% m/m	0.04	0.15
Vanadium	mg/kg	134	300
Sodium	mg/kg	24	
Aluminium	mg/kg	7	
Silicon	mg/kg	9	
Iron	mg/kg	14	
Nickel	mg/kg	41	
Calcium	mg/kg	5	
Magnesium	mg/kg	LT 1	
Lead	mg/kg	LT 1	
Zinc	mg/kg	2	
Phosphorus	mg/kg	LT 1	
Potassium	mg/kg	1	
Pour Point	°C	LT 24	30
Flash Point	°C	GT 70	60

Calculated Values

Aluminium + Silicon	mg/kg	16	80
Net Specific Energy	MJ/kg	40.07	
CCAI (Ignition Quality)	-	852	

Note:
LT means Less Than, GT means Greater Than

Specification Comparison :

Results compared with amended ISO 8217:2005 specification RMG380, table 2. Based on this sample the specification is met.

Operational Advice

Approximate fuel temperatures:

Injection:
140°C for 10 mm²/s
125°C for 15 mm²/s
115°C for 20 mm²/s
110°C for 25 mm²/s

Transfer :
40°C

Sulfur - Increased corrosive wear of piston rings and liners is possible at this
sulfur level if the Base Number of the oil in the crankcase is not high enough.
Please refer to the engine manufacturer's recommendations.

Best Regards,
On behalf of DNV Petroleum Services Pte Ltd
Qamar Hussain
Technical Advisor

Bunkering on 26-April-2012

From: <GT4000@dnvps.com>
To: <SZielonka@rccl.com>
Cc: <tmurrell@rccl.com>,<jhalvorsen@rccl.com>, <stiliyan.dimov@wartsila.com>, <nv_chiefengineer@rccl.com>,<fuelorders@rccl.com>, <JVainio@rccl.com>, <nv_chiefengineerjr@rccl.com>
Date: 05/02/2012 03:31 PM
Subject: NAVIGATOR OFTHE SEAS, FUEL ANALYSIS REPORT, BARCELONA, 26-APR-2012

To: ROYAL CARIBBEAN INTERNATIONAL
Attn: Mr Simon Zielonka
Attn: Ms Tracy Murrell
Attn: Mr Jan-Erik Halvorsen
Attn: Mr Paul Litvinov, Director, Global Fuel Sourcing
Attn: Mr Juha Vainio

Cc: WARTSILA NA INC
Attn: Mr Stiliyan Dimov, Contract Manager

Cc: The Master Of 'NAVIGATOR OF THE SEAS'
Attn: Chief Engineer
Attn: Junior Chief Engineer

DNV Petroleum Services - Fuel Analysis Report dated: 02-May-2012

Vessel: NAVIGATOR OF THE SEAS (9227508)

Sample Number	ROT1213166
Product Type	(HFO)
Bunker Port	BARCELONA
Bunker Date	26-Apr-2012
Sampling Point	SHIP MANIFOLD
Sampling Method	CONTINUOUSDRIP
Sent From	BARCELONA, SPAIN
Date Sent	27-Apr-2012
Arrived at Lab	01-May-2012
Supplier	RYTTSA
Loaded From	GREENOIL
Quantity per C.Eng.	UNKNOWN

Seal Data DNVPS, SEAL INTACT, 5935911

Related Samples	
Supplier	5935912
Ship	5935913
Ship (DNVPS MARPOL)	5935914

Receipt Data	Unit	
Source Of Data*		Ch.Eng
Density @ 15°C	kg/m^3	986.3
Viscosity @ 50°C	mm^2/s	380.0

Sulfur % m/m 3.50

*Please include a copy of the Bunker Delivery Note (BDN).

Test Parameter	Unit	Result	RMG380
Density @ 15°C	kg/m³	981.3	991.0
Viscosity @ 50°C	mm²/s	344.4	380.0
Water	% V/V	0.1	0.5
Micro Carbon Residue	% m/m	16	18
Sulfur	% m/m	2.27	3.50
Total Sediment Potential	% m/m	0.01	0.10
Ash	% m/m	0.06	0.15
Vanadium	mg/kg	174	300
Sodium	mg/kg	24	
Aluminium	mg/kg	6	
Silicon	mg/kg	11	
Iron	mg/kg	40	
Nickel	mg/kg	56	
Calcium	mg/kg	8	
Magnesium	mg/kg	6	
Lead	mg/kg	LT 1	
Zinc	mg/kg	2	
Phosphorus	mg/kg	LT 1	
Potassium	mg/kg	2	
Pour Point	°C	LT 24	30
Flash Point	°C	GT 70	60

Calculated Values			
Aluminium + Silicon	mg/kg	17	80
Net Specific Energy	MJ/kg	40.54	
CCAI (Ignition Quality)	-	843	

Note:
LT means Less Than, GT means Greater Than

Specification Comparison :

Results compared with amended ISO 8217:2005 specification RMG380, table2. Based on this sample the specification is met.

Operational Advice

Approximate fuel temperatures:

Injection:
140°C for 10 mm²/s
125°C for 15 mm²/s
115°C for 20 mm²/s
105°C for 25 mm²/s

Transfer :
40°C

Best Regards,
On behalf of DNV Petroleum Services Pte Ltd

Jeroen de Vos
Station Manager

End of Report for NAVIGATOR OF THE SEAS

Reference to part(s) of this report which may lead to misinterpretation is prohibited.

Bunkering on 3-May-2012

From: <GT4000@dnvps.com>
To: <SZielonka@rccl.com>
Cc: <tmurrell@rccl.com>,<jhalvorsen@rccl.com>, <stiliyan.dimov@wartsila.com>, <nv_chiefengineer@rccl.com>,<fuelorders@rccl.com>, <JVainio@rccl.com>, <nv_chiefengineerjr@rccl.com>
Date: 05/07/2012 04:48 PM
Subject: NAVIGATOR OFTHE SEAS, FUEL ANALYSIS REPORT, PIRAEUS, 03-MAY-2012

To: ROYAL CARIBBEAN INTERNATIONAL
Attn: Mr Simon Zielonka
Attn: Ms Tracy Murrell
Attn: Mr Jan-Erik Halvorsen
Attn: Mr Paul Litvinov, Director, Global Fuel Sourcing
Attn: Mr Juha Vainio

Cc: WARTSILA NA INC
Attn: Mr Stiliyan Dimov, Contract Manager

Cc: The Master Of 'NAVIGATOR OF THE SEAS'
Attn: Chief Engineer
Attn: Junior Chief Engineer

DNV Petroleum Services - Fuel Analysis Report dated: 07-May-2012

Vessel: NAVIGATOR OF THE SEAS (9227508)

Sample Number	ROT1213841
Product Type	(HFO)
Bunker Port	PIRAEUS
Bunker Date	03-May-2012
Sampling Point	SHIP MANIFOLD
Sampling Method	CONTINUOUSDRIP
Sent From	ATHENS
Date Sent	03-May-2012
Arrived at Lab	05-May-2012
Supplier	AEGEAN
Loaded From	AEGEAN XII
Quantity per C.Eng.	700

Seal Data DNVPS, SEAL INTACT, 5935891

Related Samples	
Supplier	5935892
Ship	5935893
Ship (DNVPS MARPOL)	5935894

Receipt Data	Unit	
Source Of Data*		Ch.Eng
Density @ 15°C	kg/m^3	987.6
Viscosity @ 50°C	mm^2/s	352.0

Sulfur % m/m 2.45

*Please include a copy of the Bunker Delivery Note (BDN).

Test Parameter	Unit	Result	RMG380
Density @ 15°C	kg/m³	985.8	991.0
Viscosity @ 50°C	mm²/s	350.1	380.0
Water	% V/V	0.1	0.5
Micro Carbon Residue	% m/m	14	18
Sulfur	% m/m	2.38	3.50
Total Sediment Potential	% m/m	0.01	0.10
Ash	% m/m	0.06	0.15
Vanadium	mg/kg	151	300
Sodium	mg/kg	51	
Aluminium	mg/kg	5	
Silicon	mg/kg	8	
Iron	mg/kg	32	
Nickel	mg/kg	45	
Calcium	mg/kg	11	
Magnesium	mg/kg	1	
Lead	mg/kg	LT 1	
Zinc	mg/kg	LT 1	
Phosphorus	mg/kg	LT 1	
Potassium	mg/kg	LT 1	
Pour Point	°C	LT 24	30
Flash Point	°C	GT 70	60

Calculated Values			
Aluminium + Silicon	mg/kg	13	80
Net Specific Energy	MJ/kg	40.45	
CCAI (Ignition Quality)	-	848	

Note:
LT means Less Than, GT means Greater Than

Specification Comparison :

Results compared with amended ISO 8217:2005 specification RMG380, table2. Based on this sample the specification is met.

Operational Advice

Approximate fuel temperatures:

Injection:
140°C for 10 mm²/s
125°C for 15 mm²/s
115°C for 20 mm²/s
105°C for 25 mm²/s

Transfer :
40°C

Best Regards,
On behalf of DNV Petroleum Services Pte Ltd

Dennis Pronk
Technical Advisor

End of Report for NAVIGATOR OF THE SEAS

Reference to part(s) of this report which may lead to misinterpretation is prohibited.