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Project Report 2018/2019 Non-Road Mobile Machinery (NRMM)

Plant Emissions & Fuel Consumption Analysis

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1.0 Acknowledgements

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Cover photograph Volvo L220F

2.0 Executive Summary

Due to stringent exhaust emissions legislation there is continuous pressure on owners of commercial off road diesel driven vehicles and machinery, also known as Non Road Mobile Machinery (NRMM), to replace or upgrade their equipment or invest in new ways to reduce the pollutant emissions from combustion engines installed in NRMM, which in turn reduces their carbon footprint.

Engine emissions standards for NRMM are set by the European Union under Regulation (EU) 2016/1628 of the European Parliament, which sets the requirements relating to gaseous and particulate pollutant emission limits and type approval for internal combustion engines. Internal combustion engines installed in NRMM significantly contribute to air pollution by emitting carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), nitrous oxide compounds (NO_x) and particulate matter (PM).

The NRMM EU Regulation defines emission limits for engines with different power ratings and applications. It also stipulates the procedure that engine manufacturers must follow in order to obtain type approval for their engines.

This report studies three pieces of NRMM heavy plant used by a port operating company. Emissions and fuel consumption readings were recorded over a three month period before and after the addition of the fuel additive, Aquasolve™. The plant was tested in workshop conditions and the data gathered for analysis.

The results demonstrate a significant reduction in emissions and fuel consumption when the additive is used. The figures derived from the emissions reductions and cost benefit analysis also demonstrate the potential savings if the plant was operating at the conservative figure of 500 operating hours annually using the additive.

3.0 Introduction

In November 2018 CFCS conducted emissions and fuel consumption analysis to gather baseline readings on three items of NRMM plant, of varying sizes and power ratings, used for cargo handling operations by a port operating company.

The three items of NRMM plant have stringent routine maintenance and inspection regimes which are undertaken at periodic intervals.

The objective of the report was to gather data before and after adding the fuel additive Aquasolve™. The measured values were analysed to provide data on the emissions and fuel consumption readings obtained.

The AGS-688 Gas Analyser (Fig.1) was used to establish the exhaust gas emissions for carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2) and nitrous oxide compounds (NO_X).

Fig. 1: AGS-688 Gas Analyser

The fuel additive Aquasolve™ was added to each machines fuel tank following baseline readings, consisting of a initial corrective dose (double the maintenance dose), followed by the recommended maintenance dose at a ratio of 1:1000 (1ltr additive to 1000ltrs fuel). For example, if the fuel tank received 100ltrs of fuel the required dose rate was 100ml of Aquasolve™. The emissions testing and fuel consumption data analysis continued throughout 2018, up to and including 14th February 2019.

4.0 Non-Road Mobile Machinery (NRMM)

NRMM covers a wide variety of machinery typically used off the road. This can range from lawn mowers, generators and forklifts, to specialist equipment and machinery such as wheeled loaders and cranes used in the construction sector and in port facilities.

The cost to replace NRMM is significant to business owners and operators and to upgrade existing equipment with emission reduction technology can be expensive and challenging. End users are constantly researching ways to prolong the operating life of existing equipment for as long as possible, maintaining efficiencies and keeping within the emission

regulations standards. If NRMM is well maintained and inspected frequently it can run efficiently for many years which is why it is important to research and develop alternative approaches in reducing harmful emissions and improving efficiencies.

5.0 Regulatory Standards for NRMM

For regulatory purposes, NRMM is defined as “any mobile machine, transportable industrial equipment or vehicle with or without body work, not intended for the use of passenger or goods transport on the road, in which an internal combustion engine is installed” (European Commission, 1997)[1].

Pollutant emissions from combustion engines installed in NRMM significantly contribute to air pollution by emitting carbon monoxide (CO), carbon dioxide (CO_2), oxygen (O_2), nitrous oxide compounds (NO_X) and particulate matter (PM). Emissions from the engines are stipulated in Regulation (EU) 2016/1628 of the European Parliament. The regulation defines emission limits for engines with different power ranges and applications. It also stipulates the procedure that engine manufacturers must follow in order to obtain type approval for their engines.

Almost all new NRMM engines will be subject to emission limits. The latest regulation encompasses more stringent emissions standards known as Stage V, similar to the Euro 6 Standard for HGV’s and buses.

NRMM emission standards apply to new engines when first placed on the market but there is a considerable number of older plant and equipment which have higher emission values. This could be due to there being less stringent regulations at the time of equipment manufacture or there were no emission standards at that time.

Additional programs to control emissions have been introduced such as the Low Emission Zone (LEZ) for NRMM in Greater and Central London, where it requires plant and equipment between 37 and 560 kW to meet Stage IIIA and IIIB emission standards. It is understood in 2020 the requirements will be tightened to Stage IIIB and Stage IV standards[2].

In 2019 the government will publish guidelines to advise ports on how to develop effective Air Quality Strategies. The strategies will set out plans to reduce emissions across the ports and associated waterways, including emissions from shore activities and visiting ships. Following publication of the guidelines, ports will be required to produce Air Quality Strategies by the end of 2019.

6.0 Aquasolve™

Aquasolve™ is a family of compounds which are ash less, non-metallic and totally organic, developed for use as fuel components for all liquid combustible fuels. The use of the unique formula reduces emissions, increases drive ability and improves efficiency. Aquasolve™ does this by delivering the fuel to the engine in a state which allows for a more complete combustion. Engine testing at major laboratories has shown it substantially reduces total unburned hydrocarbons (HC), Carbon Monoxide (CO), Nitrous Oxide compounds (NO_x), Carbon Dioxide (CO_2), Smoke and Particulates in diesel.

In addition, the unique molecular binding properties of Aquasolve™ prevents phase separation between fuel mixtures that are contaminated by water. Depending on the weather conditions 3-6% of water is present as condensation in all fuel systems. The use of Aquasolve™ can provide a solution to the water contamination in fuel, therefore increasing the effective power delivered to the engine[3].

7.0 Test Information and Results

The tests were conducted in workshop conditions and all fuel and fuel additive replenishments were supervised. Full test result print outs and vehicle reports can be provided upon request.

Test Equipment Used (Cert. of Conformity and test certificates can be produced upon request)
AGS-688 with SGD-010 Diesel Emission Upgrade
Serial No:150615000189 (2018)
AGS-688 with SGD-010 Diesel Emission Upgrade
Serial No:181130000140 (2019)


Fig. 2: Volvo L220F


Fig. 3: CASE 721FXR

Fig. 3: Manitou MT932

Plant Details:	Plant Details:	Plant Details:
Make: Volvo	Make: CASE	Make: Manitou
Model: L220F	Model: 721FXR	Model: MT932
DOM: 2008	DOM: 2012	DOM: 2007
Serial No: On request	Serial No: On request	Serial No: On request
Power: 259kW	Power: 145kW	Power: 61.5kW
Fuel Tank: 370ltrs	Fuel Tank: 253ltrs	Fuel Tank: 120ltrs

Testing Method Emissions Readings:

Pre-dosing readings were obtained to establish baseline figures. Tests were then conducted with the addition of Aquasolve™ as follows:

1) Test with engine warm at idle
2) Test with engine warm at 1200 RPM (fast idle)

Testing Method Fuel Consumption Readings:

Pre-dosing readings were obtained to establish baseline figures. Tests were then conducted with the addition of Aquasolve™ as follows:

1) Record amount of fuel supplied to replenish machines tank
2) Add Aquasolve™ at a ratio of 1:1000 (every 100ltrs fuel added, 100ml Aquasolve™ added)

Results

Volvo FLS L220F 259kW (Fuel Tank Capacity 370ltrs)

n.b Full test results and Emissions Analyser AGS-688 Exhaust Gas printouts available on request.

Emissions Averages Pre-Aquasolve	
CO	0.009
CO2	1.8
O2	18.06
NOx	159

Emissions Averages Post-Aquasolve Added		
CO	0.0042	53% Reduction
CO2	0.7333	59.3% Reduction
O2	19.6	8.5% Increase
NOx	54.7	66% Reduction

Fuel Usage Pre-Aquasolve	
Fuel Used Ltrs	434
Hours	22
Litres per hour	19.7

Fuel Usage Post-Aquasolve Added	
Fuel Used Ltrs	1024
Hours	124
Litres per hour	8.3
Reduction %	58%

Cost Analysis / Benefit on Fuel Usage			
	Without Aquasolve	With Aquasolve	Reductions / Benefits
Hours	124	124	N/A
Litres per hour	19.7	8.3	11.4 l/h
Fuel Used Ltrs	2443	1024	1419 ltrs
Fuel Cost @ 50p p/l	£1,222	£512	£710
CO2 (@ 2.68 Kg/ltr)	6547	2744	3803Kg CO2
CO2 % Reduction			58%
Aquasolve Added ml		1764	
Aquasolve Cost (FOC for Trial)			£44

CASE FLS 721FXR 145kW (Fuel Tank Capacity 253ltrs)

Emissions Averages Pre-Aquasolve	
CO	0.012
CO2	1.25
O2	18.82
NOx	135

Emissions Averages Post-Aquasolve Added		
CO	0.011	8% Reduction
CO2	1.4	12% Increase
O2	18.64	1% Reduction
NOx	137.62	1.9% Increase

Fuel Usage Pre-Aquasolve	
Fuel Used Ltrs	43
Hours	173
Litres per hour	4.023

Fuel Usage Post-Aquasolve Added	
Fuel Used Ltrs	594
Hours	222
Litres per hour	2.67
Reduction %	34%

Cost Analysis / Benefit on Fuel Usage			
	Without Aquasolve	With Aquasolve	Reductions / Benefits
Hours	222	222	N/A
Litres per hour	4.023	2.67	1.35 l/h
Fuel Used Ltrs	893	594	299 ltrs
Fuel Cost @ 50p p/l	£447	£297	£150
CO2 (2.68 Kg/ltr)	2393	1591	802Kg CO2
CO2 % Reduction			33%
Aquasolve Added ml		1332	
Aquasolve Cost (FOC for Trial)			£33

Manitou Telehandler MT932 No.13 61.5kW (Fuel Tank Capacity 120ltrs)

Emissions Averages Pre-Aquasolve	
CO	**0.011**
CO2	**1.55**
O2	**18.49**
NOx	**171**

Emissions Averages Post-Aquasolve Added		
CO	**0.011**	**No Change**
CO2	**1.65**	**6.4% Increase**
O2	**16.32**	**11.7% Reduction**
NOx	**153.78**	**10% Reduction**

Fuel Usage Pre-Aquasolve	
Fuel Used Ltrs	**116**
Hours	**34**
Litres per hour	**3.41**

Fuel Usage Post-Aquasolve Added		
Fuel Used Ltrs		**192**
Hours		**126**
Litres per hour		**1.52**
Reduction %		**55.40%**

Cost Analysis / Benefit on Fuel Usage			
	Without Aquasolve	**With Aquasolve**	**Reductions / Benefits**
Hours	**126**	**126**	**N/A**
Litres per hour	**3.41**	**1.52**	**1.89 l/h**
Fuel Used Ltrs	**430**	**192**	**238 ltrs**
Fuel Cost @ 50p p/l	**£215**	**£96**	**£119**
CO2 (2.68 Kg/ltr)	**1152**	**515**	**637Kg CO2**
CO2 % Reduction			**55%**
Aquasolve Added ml		**348**	
Aquasolve Cost (FOC for Trial)			**£9**

CO2 Emission Savings

Considering the data gathered over the three month testing period, the three items of plant contributed to a combined total emissions reduction / benefit of 5242 Kg CO_2. This is the equivalent of removing two vehicles from the road per year (based on the New Euro 6 Ford Focus Estate, running 12,000 miles per year, using 900 litres of fuel, which is equal to 2,412 Kg CO_2).

8.0 Potential Emission Reductions and Cost Savings

The emissions and fuel consumption data has been gathered over a short period of three months with limited plant operational hours. The data in the tables below represents the potential emission reductions and cost savings that could be obtained if the plant was operating at 500 operating hours annually.

The Aquasolve™ test studies to date, and engine bench test data, have shown a minimum of 10% fuel reduction, along with all the other benefits seen with the emission testing and fuel quality benefits. Fuel consumption data can vary considerably depending on surface conditions, operator behaviour and the type of work (engine under different load conditions) the machine is being used for, which can have significant increases or reductions on fuel consumption.

Due to the irregular readings obtained on fuel consumption CFCS conducted further investigations. The fuel report carried out in 2018 highlighted that the samples contained wax platelets. Dispensed fuel with wax platelets will have a considerably higher calorific value than standard in specification fuel, giving more power with a reduction in fuel consumption. Aquasolve™ solubilises wax platelets back into the fuel and will not block engine filters, but also adds to the efficiency of the fuel consumption by its chemical properties.

The tables below include the raw data provided from the testing period and the minimum fuel reduction percentage expected of 10%.

Volvo L220F

Potential Cost & CO2 Benefits on 500hrs Annual Usage					
	Without Aquasolve	With Aquasolve	Reductions / Benefits (*based on test period data only)	With Aquasolve	Reductions / Benefits (*based on min 10% fuel reduction)
Hours	500	500	N/A	500	N/A
Litres per hour	19.7	8.3	11.4 l/h	17.73	1.97 l/h
Fuel Used Ltrs	9850	4150	5700 ltrs	8865	985 ltrs
Fuel Cost @ 50p p/l	£4,925	£2,075	£2,850	£4,433	£492
CO2 (@ 2.68 Kg/ltr)	26398	11122	15276Kg CO2	23758	2640Kg CO2
CO2 % Reduction			58%		10%
Aquasolve Added ml		4150		8865	
Aquasolve Cost (FOC for Trial)			£104		£222

CASE 721FXR

Potential Cost & CO2 Benefits on 500hrs Annual Usage					
	Without Aquasolve	With Aquasolve	Reductions / Benefits (*based on test period data only)	With Aquasolve	Reductions / Benefits (*based on min 10% fuel reduction)
Hours	500	500	N/A	500	N/A
Litres per hour	4.023	2.67	1.35 l/h	3.62	0.4 l/h
Fuel Used Ltrs	2011.5	1335	676.5 ltrs	1810	201 ltrs
Fuel Cost @ 50p p/l	£1,006	£668	£338	£905	£101
CO2 (@ 2.68 Kg/ltr)	5391	3578	1813Kg CO2	4851	540Kg CO2
CO2 % Reduction			34%		10%
Aquasolve Added ml		1335		1810	
Aquasolve Cost (FOC for Trial)			£33		£45

Manitou MT932

Potential Cost & CO2 Benefits on 500hrs Annual Usage					
	Without Aquasolve	With Aquasolve	Reductions / Benefits (*based on test period data only)	With Aquasolve	Reductions / Benefits (*based on min 10% fuel reduction)
Hours	500	500	N/A	500	N/A
Litres per hour	3.4	1.52	1.35 l/h	3.06	0.34 l/h
Fuel Used Ltrs	1700	760	940 ltrs	1530	170 ltrs
Fuel Cost @ 50p p/l	£850	£380	£470	£765	£85
CO2 (@ 2.68 Kg/ltr)	4556	2037	2519Kg CO2	4100	456Kg CO2
CO2 % Reduction			55%		10%
Aquasolve Added ml		760		1530	
Aquasolve Cost (FOC for Trial)			£19		£38

Potential CO2 Emission Savings

If the plant was operating at 500 operating hours annually with additive and we utilised the data gathered from the testing period, it provides a combined total emissions reduction / benefit of 19608 Kg CO2. This is the equivalent of removing eight vehicles from the road per year (based on the New Euro 6 Ford Focus Estate, running 12,000 miles per year, using 900 litres of fuel, which is equal to 2,412 Kg CO2).

If the plants reductions were based on the minimum of 10% this provides a combined total emissions reduction of 3636kg CO2.

9.0 Other Plant Tested

(Data available upon request)

In February 2019 other models of NRMM plant were made available. The plant was tested and data gathered but due to the limited trial period and not having the benefit of previous fuel consumption data, the findings are not as detailed as the original plant made available.

Following baseline readings and the addition of Aquasolve™ a Volvo FLS 120H (2015 model) demonstrated a 40% reduction in CO_2 and a 65.8% reduction in NO_X readings and the Manitou MT835 (2015 model) gave a reduction of 2.4% in CO_2 and a 41.5% reduction in NO_X readings, which was very pleasing.

An interesting point for discussion came from the results obtained on a new 2017 registered Liebherr LH110M, 300kW Tier 4 Material Handler, which was tested for baseline readings only. The data showed average readings for CO_2 and NO_X of 2.3% volume and 166ppm volume respectively which demonstrate that the readings are relatively high for a machine with exhaust emission reduction systems fitted.

Uncharacteristic emission readings were obtained on the plant made available fitted with DEF and SCR systems and a further understanding as to the operation and effects of the systems is detailed below:

Exhaust Emission Reduction Systems
DEF (Diesel Exhaust Fluid) AdBlue Injection
SCR (Selective Catalytic Reduction)

The systems are designed to be functional in reducing emissions at maximum operating temperature only. The SCR system stores harmful emissions until the correct catalytic temperature is reached. The sensors on the system communicate with the DEF controller to inject the AdBlue. It works by converting the harmful nitrogen oxides in the exhaust fumes to nitrogen (N2) and water (H2O). However, the SCR cools very quickly if the equipment work load changes and the SCR becomes saturated with NOx emissions.

10.0 Conclusions

The use of Aquasolve™ has demonstrated that controlling the fuel quality ensures optimum performance in fuel usage and a reduction in harmful emissions, this in turn reduces the carbon footprint in an environmentally friendly way. The readings from the Volvo FLS L220F give a true representation of the effects of the fuel additive and correspond with our engine test bed data recorded at the City of London University, based on pre-Diesel Exhaust Fluid (DEF) (AdBlue Injection) and Selective Catalytic Reduction (SCR) combustion engines.

11.0 References

[1,2] White Paper September 2016: Technology Pathways for Diesel Engines Used in Non-Road Vehicles and Equipment.

[3]Coval Technologies Ltd