FCC

FUEL CONDITIONER

brought to you by:

ADDFUEL

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1. FCC PRESENTATION

ADDFUEL

FCC
FUEL CONDITIONER

THE COMMERCIALLY ASTUTE GREEN FUEL CONDITIONER WITH A POSITIVE ENVIRONMENTAL IMPACT

WHO IS ADDFUEL?

ADDFUEL are a West Australian owned and operated company that is attempting to make a difference to the world today which generations can live in tomorrow.

ADDFUEL have taken FCC which has over 20+ years proven history and commenced reintroducing FCC to the world after seeing the positive commercial and environmental benefits it embraces.

FCC is truly an environmentally friendly fuel conditioner that has many operating benefits to suit any industry fuel related needs. With two major operating benefits being reduced fuel usage and emissions reductions can you really over look trialling FCC?

Introducing FCC to any business daily operation will instantly see FCC at work as well as knowing you are having a guaranteed constant influence on the environment around you everyday.

“COMMERCIALLY ASTUTE GREEN FUEL CONDITIONER WITH A POSITIVE ENVIRONMENTAL IMPACT”

WHAT IS FCC?

WHAT IS FCC?

FCC is an environmentally friendly non-hazardous fuel conditioner

WHAT IS FCC?

FCC is a non-hydrocarbon, non-toxic, non-flammable formula

WHAT IS FCC?

FCC dissolves sticky contaminants (waxes & varnishes) in the fuel supply and removes carbon deposits from the engine

WHAT IS FCC?

FCC contains lubricity enhancers which are beneficial to all fuels but particularly low sulphur diesel and ethanol blended fuels

WHAT IS FCC?

FCC absorbs the water present in fuel, enabling it to pass through the combustion process in a pure combustible state

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FCC contains lubricity enhancers which are beneficial to all fuels but particularly low sulphur diesel and ethanol blended fuels

FCC absorbs the water present in fuel, enabling it to pass through the combustion process in a pure combustible state

FCC helps to negate the Sulphur found in fuel and non ULSD Diesel to reduce toxic emissions

FCC PHYSICAL MAKE UP

- Non toxic
- No hydrocarbons
- Bio degradable
- Non corrosive
- Friendly to fuel system
- pH neutral
- Environmentally friendly ingredients

THREE MAIN OPERATIONAL BENEFITS OF FCC

MAINTENANCE / SERVICING BENEFITS

Repair, maintain and protect your engines from the inside out.

- Increased lubricity levels to assist against wear.
- Extended injector, oil and fuel filter changes.
- Corrosion inhibitors for internal fuel delivery protection
- Rust inhibitors to protect fuel storage and fuel system components.
- Increased engine lifespan.

ENVIRONMENTAL BENEFITS

A Greener footprint for your company and Australia.

- Environmentally friendly product
- Significantly reduces harmful carbon emissions
- Substantial reduction in soot levels
- Significant reductions in Nitrous Oxides (NOx) emissions.
- Safer working conditions for employees

COMMERCIAL BENEFITS

Reduce one of your companies biggest expenses.

- Consistent financial savings from significantly better fuel efficacy.
- Less maintenance downtime equals improved equipment efficiency and reduction in expenditure
- Ease of implementation
- Bundled costing for continued positive environmental impact .

WHICH ENVIRONMENTALLY FRIENDLY PRODUCT CAN OFFER SUCH A COMMERCIAL RESULT?

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WHERE CAN I USE FCC?

FCC works on all engines powered by either Diesel, Petrol or Bio-Fuels

Generators
& Power Plants

Plant
& Equipment

Cars
& Trucks

Boats
& Ships

FCC THIRD PARTY TESTING AND SUPPORTING INFORMATION

THIRD PARTY EMISSIONS REPORTS CARRIED OUT

Emissions Report - Toyota Corolla	2016 Model
Emissions Report - Ford F350	
Emissions Report - Mercedes ML63 AMG	2016 Model
Emissions Report - Mitsubishi Triton	2016 Model
Emissions Report - Toyota Hilux	2005 Model

THIRD PARTY INTERTEK REPORTS

Standard Diesel & FCC Additive Technical Analysis
Standard Petrol & FCC Additive Technical Analysis on Wear Scar Diameter
Standard Diesel & FCC Additive Technical Analysis on Lubricity
Marine Fuels & FCC Additive Technical Analysis

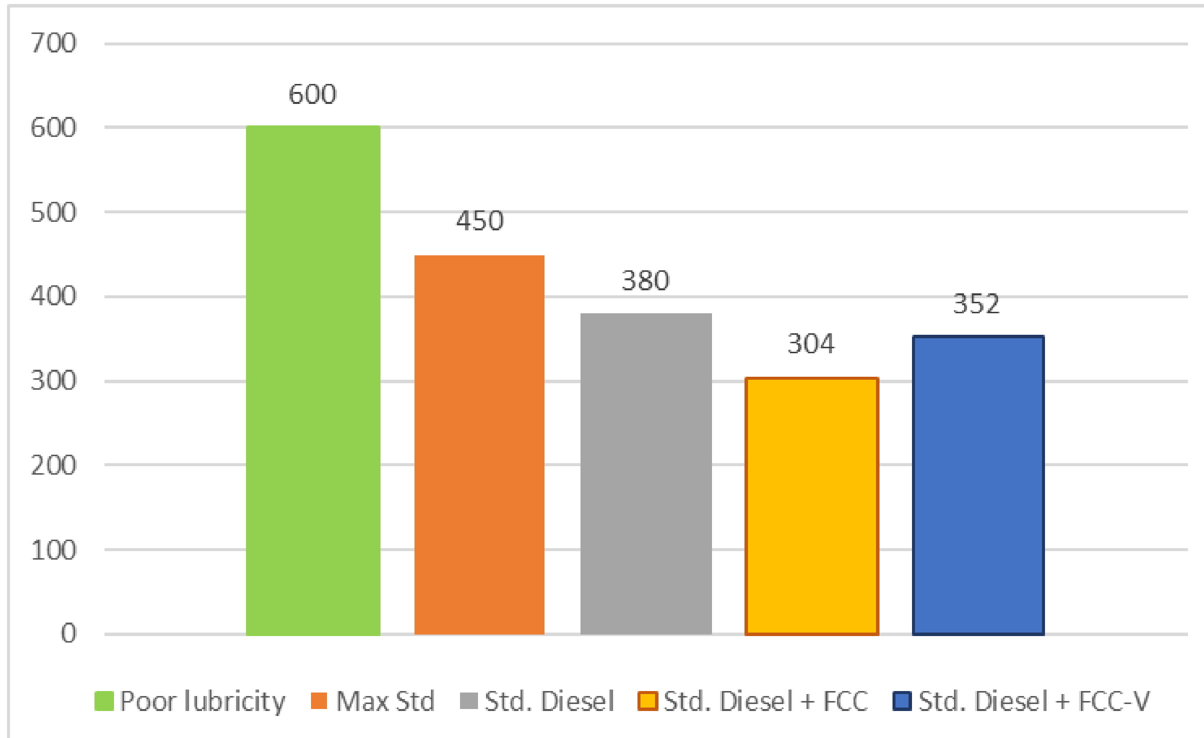
ALL OF THE ABOVE MENTIONED THIRD PARTY REPORTS CAN BE FOUND IN FULL INSIDE THIS HANDOUT BOOKLET

FCC THIRD PARTY TESTING AND COMMENTS

THIRD PARTY INTERTEK REPORTS

Standard Diesel & FCC Additive Technical Analysis on Lubricity

FCC / FCC-V improves lubricity by 7% – 20% which is a significant improvement on durability of equipment which prevents premature wear of equipment and allowing equipment to operate beyond its intended design life. This increase in lubricity directly improves engine's performance, reduces engine temperatures and minimises maintenance requirement.

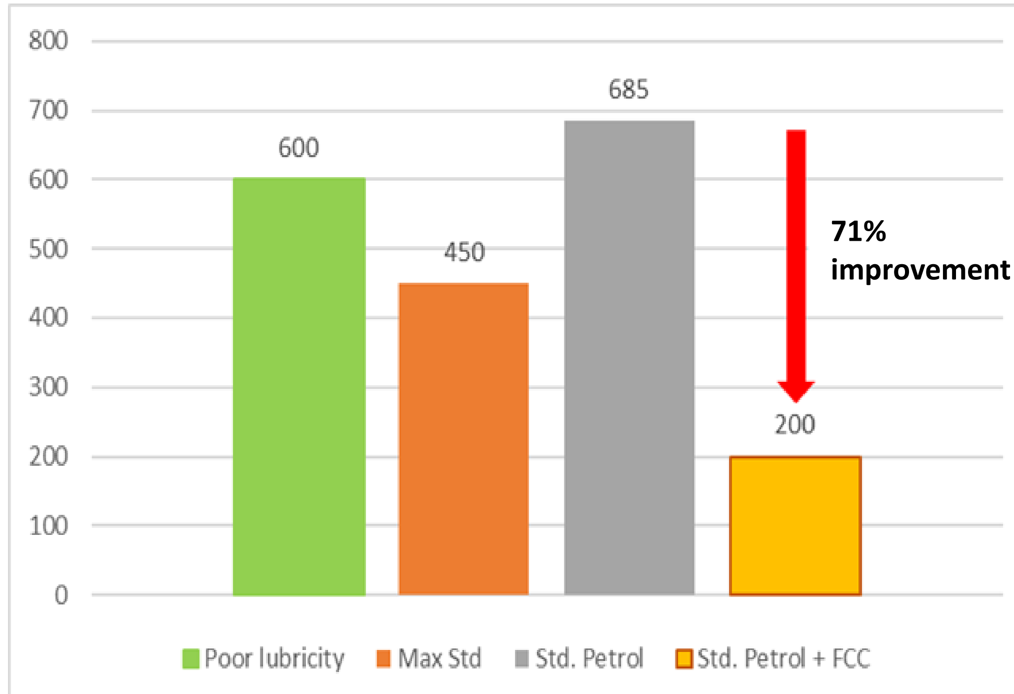


FCC THIRD PARTY TESTING AND COMMENTS

THIRD PARTY INTERTEK REPORTS

Standard Petrol & FCC Additive Technical Analysis on Wear Scar Diameter results.

The lubricity of the fuel after addition of FCC improves from 685 µm (standard petrol) to 200 µm which is a significant 71% improvement. This increase in lubricity for FCC, will significantly improve durability of equipment and prevent premature wear of equipment by allowing equipment to operate to its intended design life.



FCC THIRD PARTY TESTING AND COMMENTS

THIRD PARTY INTERTEK REPORTS

Marine Fuels & FCC Additive Technical Analysis

Fuel Conditioner Concentrate (FCC) is added directly to fuel storage tanks to eliminate the problems associated with water contamination. FCC ensures that marine fuel systems remain clean and free from corrosion, gums, and varnishes. The main benefit of FCC is derived from its regular use to maintain fuel systems free from liquid water. This prevents biological activity, reduces corrosion and inhibits reaction of the fuel with water. Regular use of FCC ensures that carburettors and fuel injectors work at peak performance eliminating poor running problems and expensive maintenance. The benefits of FCC extend throughout the fuel system.

FINDINGS

- FCC reduces sulphur content in MGO DMB by 2.7% which is an important aspect with stricter policies around sulphur in fuel, particularly in SECAs (Sulphur Emission Controlled Areas).
- FCC reduces white smoke on start up, and reduce NOx (Nitrogen Oxide) and Particulate Matter (PM) emissions (Increase in Cetane Index).
- FCC improves lubricity by a significant 16.8% in MGO and 3.2% in MGO DMB
- FCC maintains this important characteristic of the fuel for Filter Blocking Tendency (FBT) for MGO
- FCC does not impact the hazard level classification of the fuel which determines and affects the storage and handling fuel.

FCC THIRD PARTY TESTING AND COMMENTS

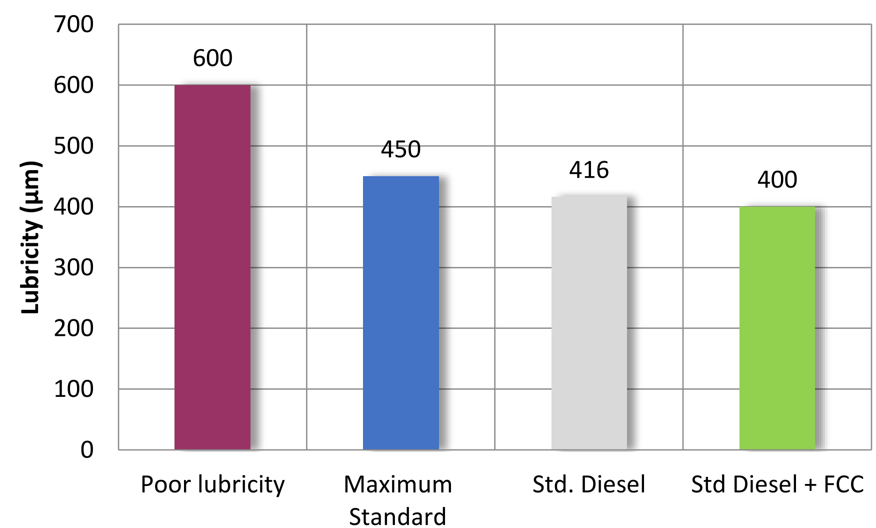
THIRD PARTY INTERTEK REPORTS

Standard Diesel & FCC Additive Technical Analysis

The report shows that when FCC is added to standard diesel the results show Safety, Environmental, Combustion, Fuel Efficiency, Performance and Ma are increased to a higher operating level which can only help any organisation using diesel fuels.

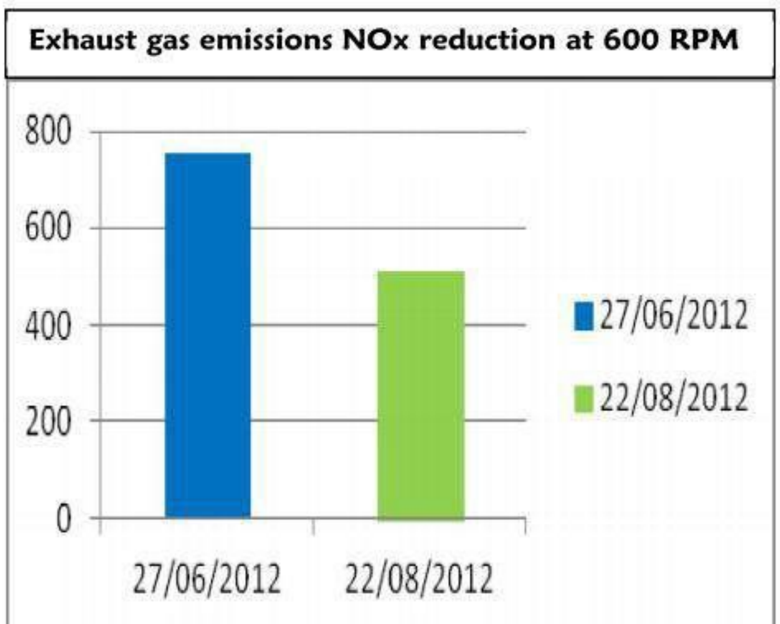
RESULTS:

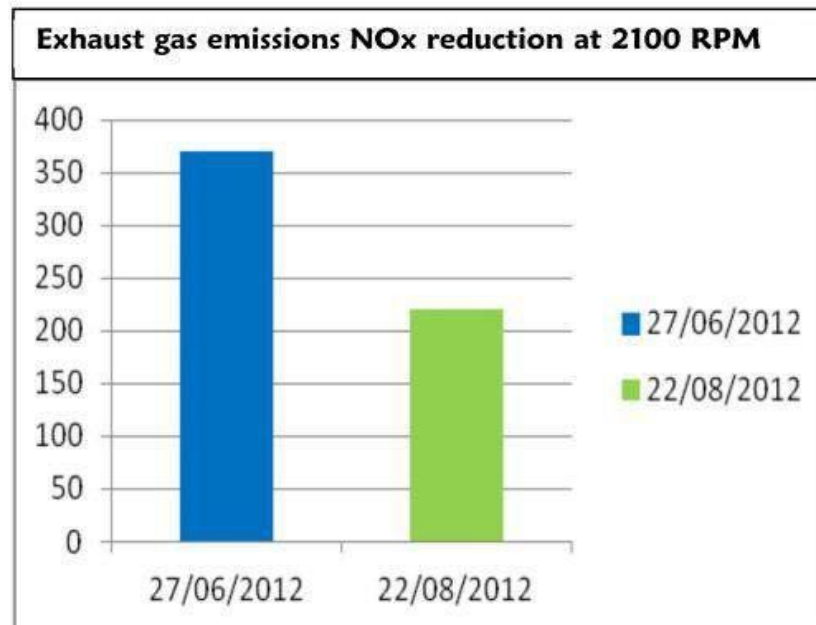
The lubricity improves by 3.8% with the addition of FCC from 416 µm to 400 µm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allowing equipment to operate to its intended design life.



TYPICAL RESULTS – Heavy Industry

- In controlled tests FCC has delivered savings of up to **16% fuel savings** on diesel powered generators, **5%+** on large diesel mining equipment and **6.5%+** on brand new diesel powered buses.
- In addition to the fuel savings, FCC **reduced NOx emission's by 40%+ and CO emissions by 30%+** in an independent test conducted by BARRICK GOLD at the Darlot mine in Western Australia.





TYPICAL RESULTS – Mining Industry

FCC Trial was conducted by BARRICK GOLD at the Darlot mine in Western Australia, 400 km north of Kalgoorlie. The trial took place over a 6 month period with data collated before, during and after the introduction of FCC to one of the mines DT10's fuel tanks. During the trial Barrick personnel routinely analysed the vehicle's oil to record soot levels as well as analysing the Nitrous Oxide and Carbon Monoxide exhaust gases. The fuel consumption was also routinely and methodically recorded throughout the trial process.

FINDINGS:

- Fuel consumption data collected showed a significant 5.3% reduction in fuel consumption.
- Nitrous Oxides (Nox), expelled through the exhaust showed a significant reduction of 40.5% during the FCC trial period.
- Carbon monoxide emissions reduced by 33% during the same trial period.
- Oil analyses taken during the trial period demonstrated soot levels reduced by 33%.

TYPICAL RESULTS – Power Station

FCC trial was conducted by EPC who oversees the power generation and distribution for the Pacific Island nation of Samoa. The main source of their electricity is through the use of diesel generators. Whilst reliable, it is costly with fuel prices at a premium across all Pacific Islands which is why EPC commenced a trial to investigate the benefits of FCC. EPC conducted a thorough 6 month analysis of FCC through extensive onsite tests relating to fuel consumption, power output and if the plants general operational behaviour changed for the better.

FINDINGS:

- Fuel consumption data collected during the trial showed a significant 4% fuel savings over the trial period.
- Exhaust temperatures showed a reduction of 10 degrees during FCC trial period with a clear reduction in blockages to the plants fuel filters while FCC was in circulation.
- FCC demonstrated a range of benefits that all equated to a more efficient working power plant.

TYPICAL RESULTS – Power Station

FCC trial was conducted by PNG Power at the Moitaka power generation and distribution site in Port Moresby. The trial was designed to demonstrate that addressing PNG fuel quality and storage issues FCC could produce genuine benefits for PNG Power as well as address the needs for cost savings initiatives.

FINDINGS:

- Better efficient use of diesel fuel and reduced fuel costs.
- Smoother and more reliable power generation due to reduced down-time during trial period.
- Virtual elimination of unscheduled, fuel-related maintenance expenses.
- Average fuel efficiency went from 3.73Kw Hours per litre to 4.97Kw Hours per litre.
- FCC reduced PNG Power's fuel bill at Moitaka by 30% during the trial period.

TYPICAL RESULTS – Trucking

As one of the largest and most respected trucking companies operating in Southern Arizona and Mexico, Manuel Huerta Trucking (MHT) are renowned in the logistics industry as innovators. MHT agreed to run an in house test with FCC on three of their 2015 Freightliners, running freight between Nogales and Mexico daily. This testing was run independently by MHT and was overseen by the company maintenance manager and maintenance executive.

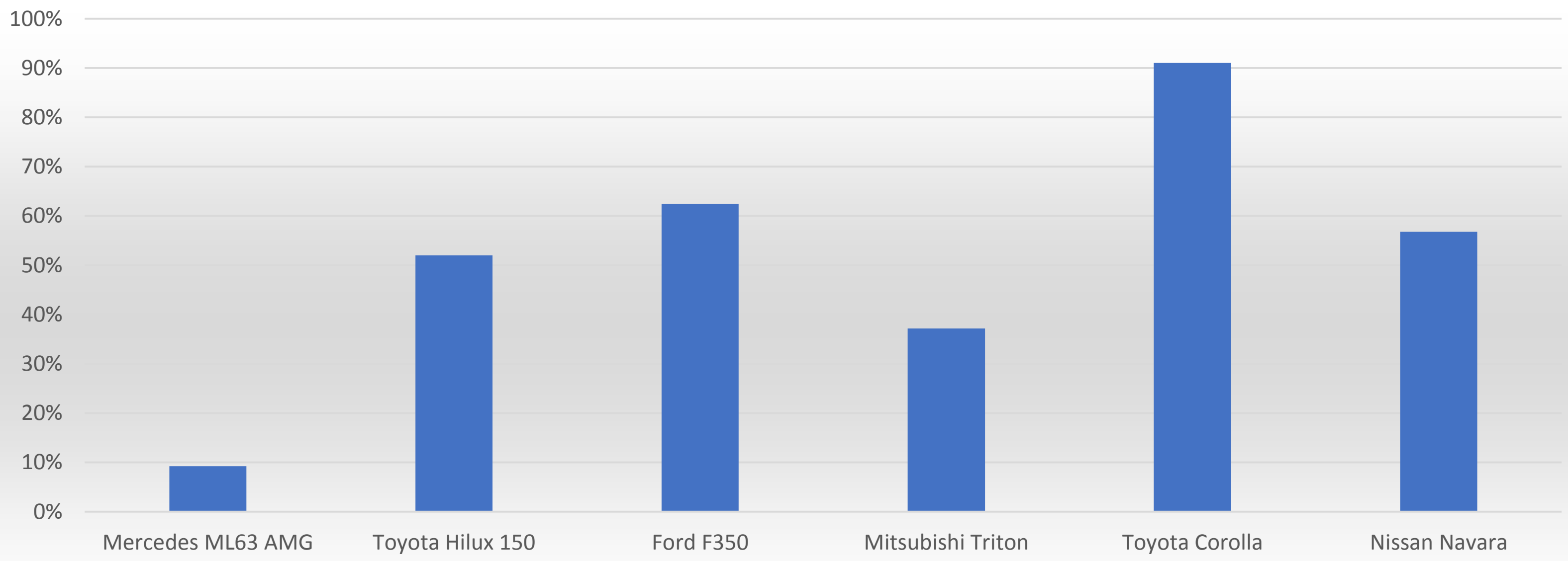
FINDINGS:

Over a combined 17,567 mile trial an average fuel savings of 12.55% was seen across the three trucks using FCC!

EMISSION REDUCTIONS

CARBON MONOXIDE (CO) GAS EMISSION REDUCTIONS AFTER FCC IS APPLIED TO THE FUEL SUPPLY OF EACH VEHICLE.

AVERAGE OF 46% REDUCTION ACROSS IDLE AND AVERAGE RPM.



SUSTAINABILITY

ADDFUEL are proud to be able to offer its clients the opportunity to make its fuel consumption completely carbon neutral and truly make a stand when it comes to protecting the environment. This is your opportunity to initiate this simple but effective opportunity to make your companies sustainability statement actually mean something and become true leaders in the carbon neutral arrangement when judged against your rivals.

Don’t hesitate to ask one of ADDFUEL management team on just how this environmental advantage can be achieved.

CURRENT FCC MARKETS

- Australia
- UK
- USA
- India
- China
- Southern Africa
- PNG
- Bangladesh

ADDFUEL THANKS YOU FOR YOUR TIME TODAY
AND WE LOOK FORWARD TO ANSWERING ANY QUESTIONS YOU MAY HAVE
& ASSISTING YOU WITH REDUCING YOUR EMISSIONS CONCERNS

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2. FCC COST BENEFITS

Assumptions

Dilution ratio	1: 4000
Cost of fuel	$1

ROI - Return on Investment

Ltrs fuel used monthly/annually		500,000	**ROI**		5,000,000	**ROI**		50,000,000	**ROI**		200,000,000	**ROI**
Litres of FCC required @ 4000:1 ratio		125			1,250			12,500			50,000	
Price per litre of FCC	$	60		$	60		$	60		$	60	
Total Cost of FCC	$	7,500		$	75,000		$	750,000		$	3,000,000	
Cost of fuel	$	500,000		$	5,000,000		$	50,000,000		$	200,000,000	
GUARANTEED 3% improved fuel efficiency	$	15,000		$	150,000		$	1,500,000		$	6,000,000	
GUARANTEED 3% Saving including FCC Cost	**$**	**7,500**	**100%**	**$**	**75,000**	**100%**	**$**	**750,000**	**100%**	**$**	**3,000,000**	**100%**
ACHIEVED EFFICIENCIES - AS PER INDEPENDENT CASE STUDIES												
5.5% improved fuel efficiency (Darlot minesite, Barrick Gold Corp)	$	27,500		$	275,000		$	2,750,000		$	11,000,000	
5.5% Saving including FCC Cost	**$**	**20,000**	**267%**	**$**	**200,000**	**267%**	**$**	**2,000,000**	**267%**	**$**	**8,000,000**	**267%**
12.5% improved fuel efficiency (Manuel Huerta Trucking, USA, MEX)	$	62,500		$	625,000		$	6,250,000		$	25,000,000	
12.5% Saving including FCC Cost	**$**	**55,000**	**733%**	**$**	**550,000**	**733%**	**$**	**5,500,000**	**733%**	**$**	**22,000,000**	**733%**

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3. CASE STUDIES

ADDFUEL

CASE STUDY: MINING

OBJECTIVE:

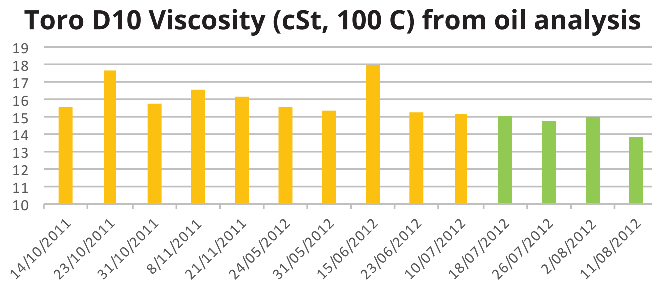
The following study was carried out to establish the effectiveness of FCC Fuel Conditioner Concentrate in a minesite environment on a DT10 TORO 50+ to seek out alternative methods to cutting costs on Barrick production operations. The trial was conducted at Barrick's Darlot mine, 400 km north of Kalgoorlie. The trial took place over 6 months from the 1st of April to the 29th of September with data collated before, during and after the introduction of FCC to the DT10's fuel tanks, the vehicle's oil was routinely analysed to record soot levels, the exhaust gases analysed for Nitrous Oxide in the exhaust, the fuel consumption was also routinely and methodically recorded.

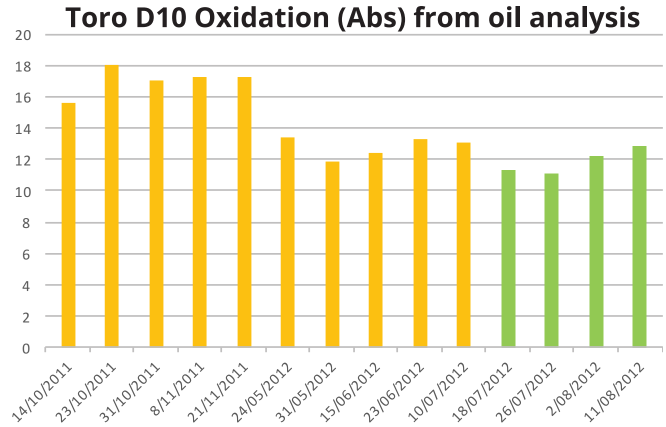
Actual vehicle used during FCC trial

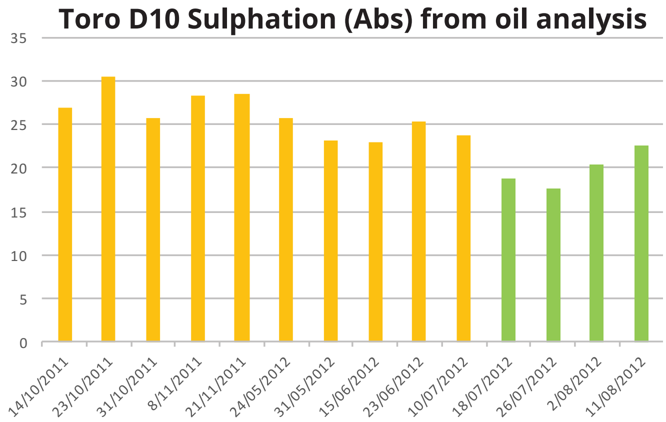
FINDINGS:

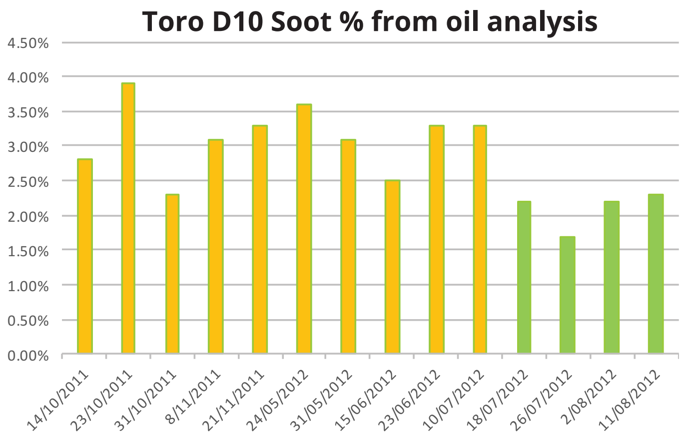
- **Fuel consumption data collected showed a significant reduction in fuel consumption with a drop of 5.3%**
- **Nitrous Oxides NOx, expelled through the exhaust showed a significant reduction, during the FCC phase. NOx levels being reduced by 40.5% at 2100RPM**
- **Carbon monoxide emissions reduced by 33%**
- **Oil analyses; demonstrated soot reduced by 33%**

These improvements in vehicle performance were apparent within hours of FCC being applied. It was found along with the reduction in fuel through the application of FCC to the vehicles fuel at a ratio of 1:4000 litres of diesel that the product provided positive results with the reduction of Nitrous Oxide, lower soot emissions and improved fuel consumption therefore improving OHSE operational performances. The engine was not opened up at the completion of the trial, however it is accepted, with all other conditions staying the same, these results were directly associated with the use of FCC removing any gums, resins, water and the breakdown of carbon.









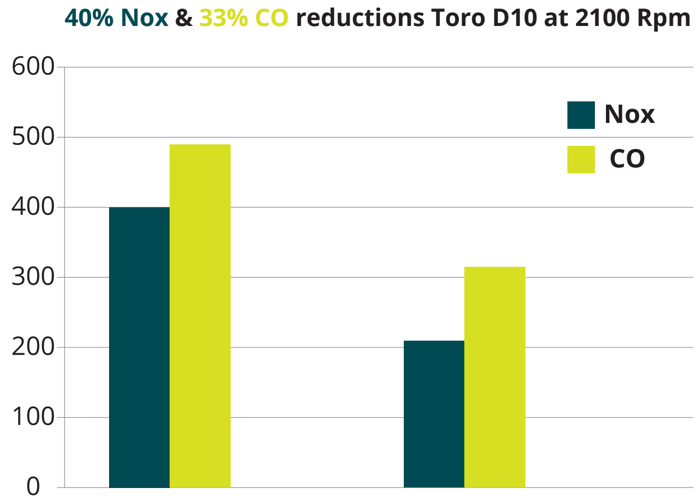
CASE STUDY: MINING

NITROUS OXIDES (NOx)

Evident in the graph to the right, depicting the Nitrous Oxide and CO results measured by Sandvik and Complete Envirotest of the DT10, shows a significant reduction once FCC was applied to the fuel.

These gas emission tests were taken whilst the DT10 was running at 600 RPM, and 2100 RPM over a six month period. The findings from the trial show a reduction of 40.54% on the amount of Nitrogen Oxide and 33% reduction in Carbon monoxide at 600RPM.

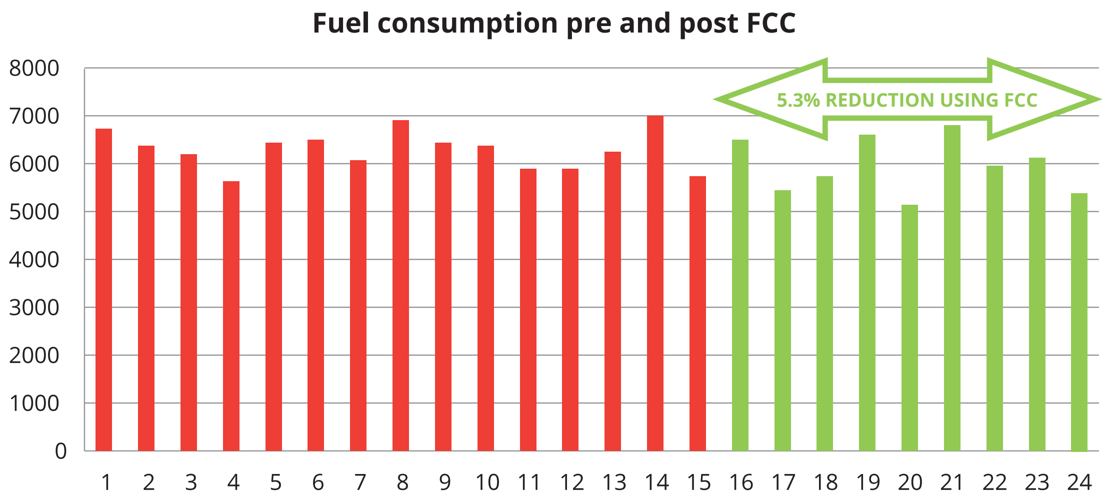
As all other test data is constant, these reductions can be credited to the use of FCC in the DT10's fuel.



FUEL CONSUMPTION

As the graph to the right shows, from the introduction of FCC to the fuel system there was an overall decrease in fuel consumption of 5.3%.

Findings are based on consumption alone.



CONCLUSION

From the data kindly provided us by Barrick, with all other variables remaining reasonably constant, reductions demonstrated in the report for Nitrous Oxides, Soot, Carbon Monoxide, contamination in the oil and the 5% reduction in fuel consumption can be credited to the use of FCC being added in to the DT10's fuel supply.

By a process of deduction it stands to reason that there will be other less apparent benefits. These benefits would be extended service intervals, longer intervals between fuel and oil filter changes. Longer engine life. Extended injector period changes possibly from the current 4000 hours to 6000 hours. Thus reducing downtime and replacement parts costs. These savings are quite capable of exceeding those from fuel.

Overall the absence of carbon and soot, clean fuel lines and injectors as well as the eradication of diesel bug means a far more efficient system that runs more smoothly and efficiently, thus reducing downtime as well as the costs involved with servicing.

INNOVATION. DESIGN. TECHNOLOGY

Creating a Better Future, Today.

CASE STUDY: DIESEL POWER STATION
Moitaka Power Station, Port Moresby, PNG

OBJECTIVE:

A trial of FCC was designed for the Moitaka Power Station in Port Moresby to demonstrate that by addressing the power station's fuel costs, quality issues and storage of the fuel in question could result in the reduction of running costs and guarantee a better operating performance from its plant and equipment, thereby running a more cost effective power supply for the community of Port Moresby and PNG. Key elements that PNG Power wanted to achieve out of the trial was:

- More efficient use of diesel fuel leading to reduced fuel bills.
- Smoother and more reliable power generation through reduced down-time due to fuel related issues.
- Virtual elimination of unscheduled, fuel-related maintenance expenses.

FCC, Moitaka trial was supervised and compiled entirely by PNG Power staff, using standard data collection and reporting techniques. These independent results will make the bases of whether or not FCC would offer the cost savings PNG Power require to protect the power plant assets and electricity output in a cost effective manner.

OBSERVATION:

These independent results make the most compelling case for the continuous use of FCC. As clearly demonstrated, the three months that FCC was present in the Moitaka fuel supply were easily the most fuel efficient months over all of 2010 and 2011 and returned PNG Power massive fuel savings for the duration of that trial.

FCC was introduced into Moitaka fuel supply on 17 October 2010 and by November FCC was thoroughly blended into the power station's fuel farm. The dosing of FCC into the fuel farm was ceased on 7 December 2010 and the fuel supply gradually reverted to its pre-FCC state, as the FCC treated fuel was consumed.

CASE STUDY: DIESEL POWER STATION

ADDFUEL

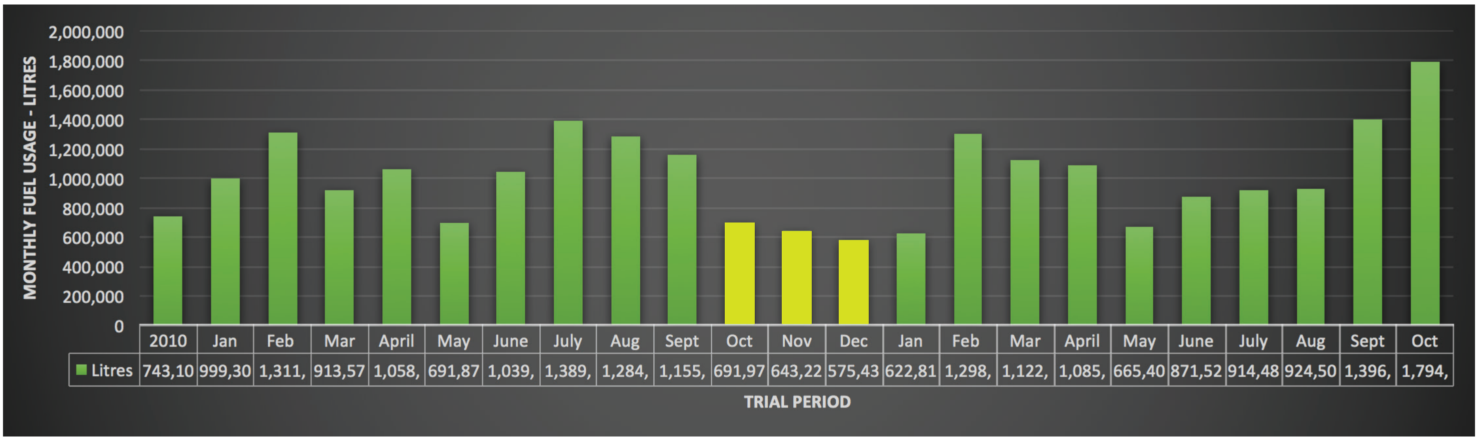
The three months FCC was added to the fuel supply were easily the most fuel efficient months Moitaka had seen over 2010 and 2011 and ever, for that matter. Even though FCC was only dosed into the fuel for 50 days (17 Oct to 7 Dec), the average fuel efficiency for this 90 day period was 4.97 Kw/H per litre with December's fuel efficiency showing a massive 5.5 kw Hours per litre of diesel. These figures with FCC in operation would reduce PNG Power's fuel bill at Moitaka by 30%!

Along with the increased fuel efficiency, the plant engineers noticed instant changes in the plant's operating performance with less black soot being visible from the exhaust during peak periods and the fuel filters showing less wax build up during the FCC implementation period with a very visible increase in wax levels as soon as the FCC trial concluded.

FINDINGS:

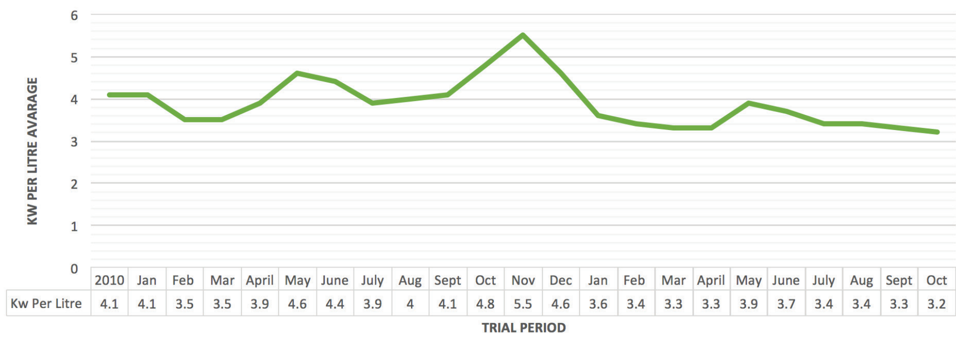
PNG Power was advised from the supplier of FCC to expect an increase in fuel efficiency from anywhere between 3-8%. On conclusion of the trial and a review of the collected data, a 30% fuel saving was achieved during the FCC dosing period. An annual savings of 30% for Moitaka would see a return of $13Million Kina ($5.5Million AUD) for PNG Power. PNG Power cannot assume this 30% savings would be achievable for a 12-24 month duration but a more achievable 10% could be assumed without hesitation. Even with this more conservative figure, fuel savings would amount to $4.4 Million Kina ($1.8Million AUD) annually at Moitaka, after the cost of FCC has been deducted.

FUEL USAGE GRAPH



The potential, accumulated fuel savings available to PNG Power across the network are substantial. In addition, there will be significant savings in both short and long term maintenance that will become more evident and measurable after a greater period of FCC usage. These potential savings are substantial enough to generate excess capital for much needed maintenance and infrastructure upgrades for Moitaka and PNG Power.

kW PER LITRE GRAPH



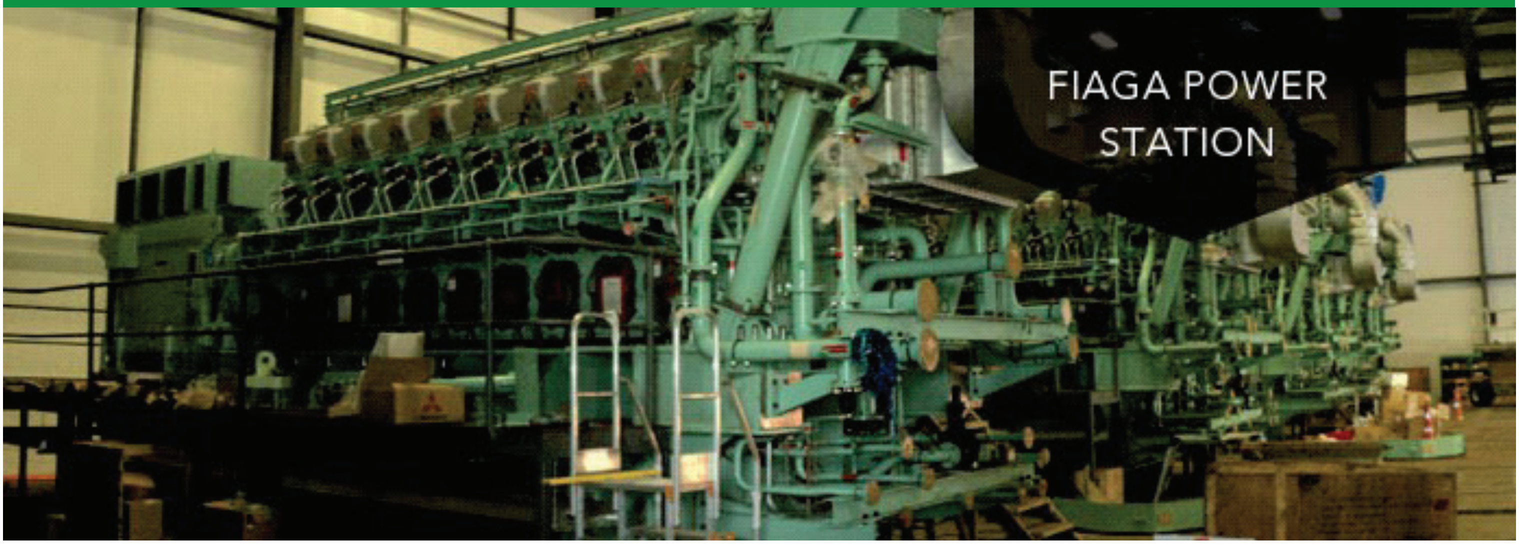
After detailed evaluation of the collected trial data and recommendations from the maintenance personnel at PNG Power I can only recommend that FCC be implemented at one of PNG Power's fossil fuelled power stations due to the proven operating performances of FCC and the instant generation of savings that can be achieved.

William Kenjibi - General Manager – PNG Power

CASE STUDY: DIESEL POWER STATION
Tanugamanono Power Station, Apia, Samoa

OBJECTIVE:

Electric Power Corporation of Samoa was concerned with the price increases in diesel fuel which were beginning to affect the reliability and affordability of electricity in Samoa. It was EPC's (Electric Power Corporation) responsibility to look at possible methods or ideas that could reduce the running costs of the Tanugamanono Power Station without compromising on supply or at the detriment of the Power Station's plant and equipment. EPC was introduced to FCC and after further internal investigation of FCC operating properties, a trial was confirmed by EPC senior management. The trial was set up for a 6 month period with a focus on monitoring the power plants fuel efficiency, kilowatt output and the temperature of the engines along with any changes in the general operation of the engines and output.



DOSING METHOD:

While reviewing the best two blending options available to us, we realised the best option was going to be the dosing of the delivery truck. We could not dose directly to the fuel farm prior to filling as there was no means to measure the amount of fuel still available in the fuel farm so we required the final diesel volume figure from the truck after the discharge to calculate the required amount of FCC required. This in turn raised the issue of how FCC would then be blended/mixed thoroughly with the diesel and we could not be sure that a suitable blend process of the two products had taken place or would take place.

Due to the these issues, the option of using the delivery truck to blend was confirmed. The standing fuel order arrived on site every 3 days. On arrival FCC would be added to the truck before it discharged into the power plant fuel farm. This would allow us to ensure the exact amount of FCC was being applied each time as the truck would hold 26,300L of diesel, so the amount of FCC required to treat the truck deliver was 6.5L per load. The discharge process from truck to fuel farm created a good mixing process to blend the FCC through the diesel.

CASE STUDY: DIESEL POWER STATION

OBSERVATION & TECHNICAL VIEW:

There were some obvious observations that we noted and experienced during this trial period:

1. Average Engine Exhaust Temperatures were dropped by 10C

This is one of the most important parameters we need to consider. The weather in Samoa is hot and sticky and exhaust temperatures need to be brought down as much as possible to work effectively & efficiently. High cylinder exhaust temperature contributes to most engine failures. Cracks on cylinder heads can be a result of high cylinder exhaust temperature, as properties of metal become fatigued when they reach certain high temperatures. High fatigue stress and brittleness of cylinder heads from high temperatures can be worsened by overdue overhauls and poor maintenance and operation.

2. Leaked fuel pump problem

We were frequently facing the problem of fuel pump leakages almost every month, sometimes 2 or 3 times. Fuel pump leaks were mostly caused by fuel starvation, water content in fuel and foreign materials entering the unit. The total cost of element, seals, delivery valve and other parts to recondition the fuel pump can be $5000+. The inclusion of FCC during the trial process put a complete stop to this issue, and there was not one fuel pump problem during the entire trial.

3. Blocked filter & strainer

This is another issue that the maintenance team would have to deal with at least once a month. During the FCC trial period, the filter and strainer did not require changing or unblocking once. The major contributing factor causing fuel pump leakage is fuel starvation due to blocked filters.

TEST 1 BEFORE ADDING FCC

TIME 2HRS	LOAD KW	TURBO SPEED	FUEL METER READING	FUEL USED	KWH X 1000	KWH PRODUCED	EFF. KWH/L	EXHAUST TEMPERATURE 1	2	3	4	5	6	7	8
10.30	3800		301330		98578625			500	470	482	476	479	476	470	440
11.00	3800		301790	460	98580415	1790	3.891	498	468	479	473	478	472	467	438
11.30	3800		302255	465	98582195	1780	3.828	498	468	478	473	476	477	468	437
12.00	3800		302718	463	98583995	1800	3.888	494	467	476	470	475	470	468	435
12.30	3800		303180	462	98585810	1815	3.929	492	472	476	469	474	471	466	438
O'RALL		0				Average	3.884								471
	3500		325010		98671460			474	461	462	454	461	456	445	424
	3500		325460	450	98673210	1750	3.889	472	459	459	453	460	455	446	424
	3500		325916	456	98674940	1730	3.794	469	459	459	453	459	454	442	423
	3500		326352	436	98676650	1710	3.922	469	459	459	453	459	454	442	423
	3500		326782	430	98678322	1672	3.888	469	454	452	449	455	447	439	420
10.55		0				Average	3.873								
															452
	2900		339783		98727808			435	430	415	430	436	425	419	411
	2900		339893	110	98728220	412	3.745	425	401	403	422	427	423	412	408
	2900		340001	108	98728634	414	3.833	429	407	409	420	433	424	412	407
	2900		340112	111	98729055	421	3.793	429	407	409	424	433	424	412	407
		0		329	3.790	1247	3.791								419
	2700		338817		98724255			435	415	415	432	439	432	418	414
	2700		339045	228	98725120	865	3.794	439	419	417	433	439	421	421	414
	2700		339271	226	98725964	844	3.735	429	405	406	424	430	425	413	411
	2700		339475	204	98726712	748	3.667	425	400	398	420	425	418	412	410
	2700		339680	205	98727437	725	3.537	421	396	397	420	422	416	411	407
		0		863	3.687	3182	3.683								419
	2100		342120		98736880			418	385	393	413	417	409	404	402
	2100		342215	95	98737222	342	3.6000	417	387	390	413	716	417	403	402
	2100		342318	103	98737566	344	3.3398	416	387	390	412	714	408	401	400
	2100		342415	97	98737910	344	3.5464	418	385	392	413	714	410	399	400
		0				Average	3.4954								
															433

TEST 2 BLEND WITH FCC

TIME 2HRS	LOAD KW	TURBO SPEED	FUEL METER READING	FUEL USED	KWH X 1000	KWH PRODUCED	EFF. KWH/L	EXHAUST TEMPERATURE 1	2	3	4	5	6	7	8
	3800		416014		99020803			470	452	455	456	461	454	444	426
	3800		416468	454	99022593	1790	3.943	507	472	481	479	483	476	474	446
	3800		416909	441	99024331	1738	3.941	476	451	434	487	461	454	443	487
	3800		417337	428	99026016	1685	3.937	479	483	437	457	462	436	446	427
10.55		0					3.940								
															461
	3600		407961		98989909			481	451	457	484	460	452	446	422
	3600		408183	222	98990777	868	3.910								
	3600		408411	228	98991670	893	3.917								
	3600		408638	227	98992550	880	3.877	477	448	434	449	456	447	441	418
	3600		408864	226	98993427	877	3.881	485	452	462	454	460	452	449	422
O'RALL		0				Average	3.896								452
	2800		421186		99041134			436	420	418	430	430	425	414	411
	2800		421419	233	99042039	905	3.884								
	2800		421649	230	99042933	894	3.887								
	2800		421880	231	99043832	899	3.892								
	2800		422114	234	99044738	906	3.872								
		0				Average	3.884								423
	2500		424292		99053284			420							
	2500		424396	104	99053683	399	3.837								
	2500		424499	103	99054076	393	3.816								
	2500		424605	106	99054481	405	3.821								
		0		104.3	3.824	399	3.824								420
	2100		342120		98736880			418							
	2100		342215	95	98737222	342	3.6000	417							
	2100		342318	103	98737566	344	3.3398	416							
	2100		342415	97	98737910	344	3.5464	418							
		0				Average	3.4954								
															417

CASE STUDY: DIESEL POWER STATION

FINDINGS:

Collected efficiencies BEFORE and AFTER adding FCC can be shown in Table 1. Mirlees engines always recommend running them where its maximum efficiency lies, which is between 80% to 90% load, above and below that range efficiency is decreased.

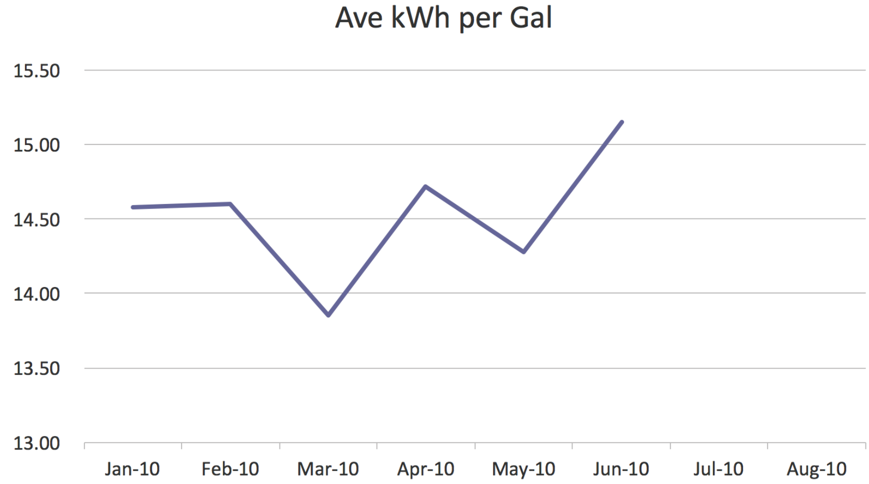
No maintenance was completed and by simply adding a blend of FCC, efficiency at various loads improved by a certain % as shown in the last two columns of Table 1.

TABLE 1

Load		Efficiency for DIESEL ONLY		DFSM		Imp. EFF	Imp. Eff
KW	%	KWH/L	$/KWH	KWH/L	$/KWH	by KWH/L	%
1500	36%	3.400	0.7724	3.450	0.7697	0.050	1.47%
2100	50%	3.495	0.7513	3.551	0.7479	0.055	1.58%
2500	60%	3.687	0.7123	3.804	0.6981	0.117	3.17%
3000	71%	3.791	0.6927	3.895	0.6818	0.104	2.74%
3500	83%	3.873	0.6781	3.980	0.6672	0.107	2.76%
3800	90%	3.884	0.6762	3.986	0.6662	0.102	2.63%

Efficiency at 90% load was improved by 2.63% or 0.102 kWh/L. Surprisingly there was a 3.17% improvement of efficiency at 60% load.

- **Results showed an increase of 3.17% improvement in the fuel efficiency.**
- **No maintenance was carried out prior to or during the trial off FCC and just by adding a blend of FCC, efficiency at various different loads improved.**
- **Efficiency at 90% load was improved by 2.63% or 0.102 kWh/L. Surprisingly there was a 3.17% improvement of efficiency at 60% load. Subsequently we could operate our plant at a lower capacity and achieve greater fuel efficiency!**



- **Based on the current fuel price and using our last year's fuel consumption report it has been estimated EPC could save over $600,000 just by introducing FCC to the Tanugamanono Power Station.**

SUMMARY & RECOMMENDATION:

In conclusion, FCC has combined benefits that work extremely well for EPC by reducing carbon emission and at the same time assist EPC in increasing profits due to FCC fuel efficiency characteristic which it has clearly shown during the 6 month trial. I have no hesitation in confirming that by adding FCC to the everyday fuel operations of the power plant that fuel and maintenance costs will reduce which is clearly in the right direction of achieving EPC's operational goal of providing Cheap and Affordable Electricity for Samoa. From the data collected during the trial and carrying out in-depth analysis of the data in question, FCC is worth investing in and is extremely cost effective to use.

Prepared by: S.Tago | Data collection by: I.Tevaga

Original report refers to Fuel Set, this was FCC exported name up to 2015

FCC FUEL CONDITIONER

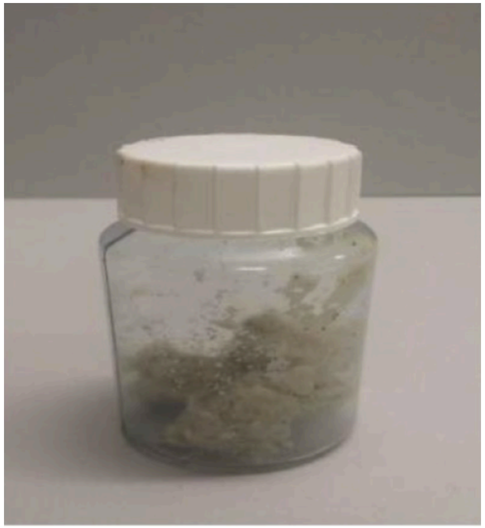
EPA Registered

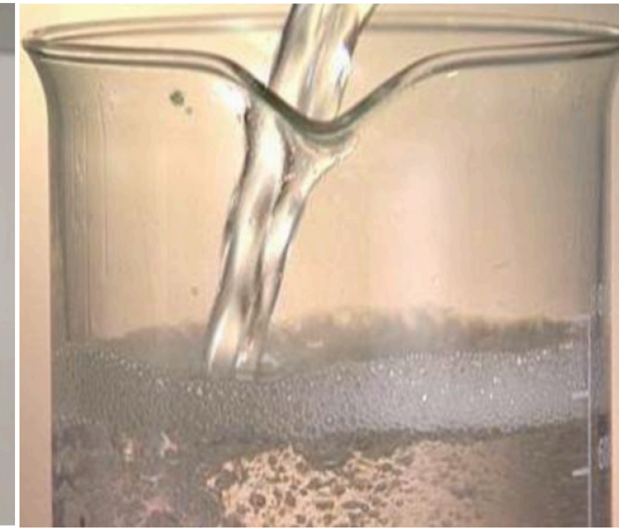
Primary Fuel Filter Clogged With Paraffin Wax Residue

Implications if left untreated:

- Increased emissions, decreased efficiency
- Fuel system failure (fuel pump, injectors)
- Direct impact on quality

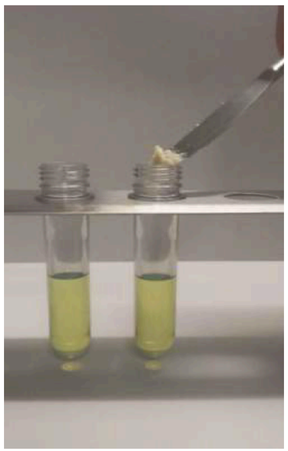
Demonstrating how FCC work's on paraffin and other waxes and gums that are common with diesel



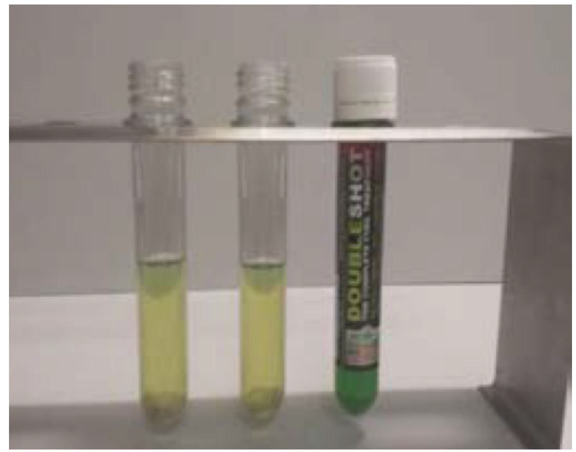


Sample of paraffin from Precoater filter

Equal amounts of paraffin is added to each

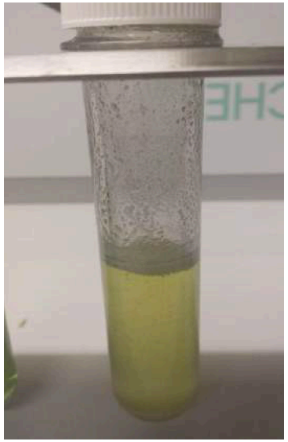


A few drops of FCC is added to the right sample



ADDFUEL **CASE STUDY: PRECOATER 6500**

FCC FUEL CONDITIONER
EPA Registered




Mixture is lightly shaken. After 1 minute the following is observed:

- Non FCC sample has left residue along the vessel
- FCC sample shows the residue almost completely dissolved “Fuel Bug” held in suspension


After 3 minutes:

- Non FCC sample has mass build-up of paraffin at base
- FCC sample show complete dilution, “Fuel Bug” still held in suspension

INDEX

4. SUSTAINABILITY

ADDFUEL

SUSTAINABILITY

ADDFUEL are proud to be able to offer its clients the opportunity to make its fuel consumption completely carbon neutral and truly make a stand when it comes to protecting the environment and make their companies true leaders in this carbon neutral initiative when blending your fuel with FCC.
Don't hesitate to ask one of ADDFUEL management team on just how this environmental advantage can be achieved.

INDEX

5. THIRD PARTY LABORATORY TEST RESULTS & REPORTS

Revision A

Standard Diesel & FCC Additive Technical Analysis on Lubricity

ADDF-REP-TA-0002

Michelle Lam

STANDARD DIESEL & FCC ADDITIVE TECHNICAL ANALYSIS ON LUBRICITY

ADDF-REP-TA-0002

Revision Number: A
Revision Date: 15/01/2017

PREPARED BY

Name	Designation	Signature	Date
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REVIEWED BY

Name	Designation	Signature	Date
Justin West	Australasian Business Development Manager		

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2 INTRODUCTION 4
2.1 DOCUMENT SCOPE 4
2.2 ABBREVIATIONS 4
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3 LUBRICITY 5
3.1 DEFINITION 5
3.2 OVERVIEW / SPECIFICATIONS 5
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1 EXECUTIVE SUMMARY

Fuel Conditioner Concentrate (FCC) is added directly to fuel storage tanks to eliminate the problems associated with water contamination. FCC ensures that vehicle fuel systems remain clean and free from corrosion, gums, and varnishes. The main benefit of the FCC is derived from its regular use to maintain fuel systems free from liquid water. This prevents biological activity, reduces corrosion and inhibits reaction of the fuel with water. Regular use of FCC ensures that carburetors and fuel injectors work at peak performance eliminating poor running problems and expensive maintenance. The benefits of FCC extend throughout the fuel system.

FCC / FCC-V improves lubricity by 7% – 20% which is a significant improvement on durability of equipment which prevents premature wear of equipment and allowing equipment to operate to its intended design life. This increase in lubricity directly improves engine's performance and minimises maintenance requirement.

2 INTRODUCTION

FCC is an innovative and scientifically proven blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's engines. It's a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency. It is suitable for use for a large variety of fuel types.

With FCC, improvements in fuel efficiency and savings in maintenance costs are achieved through cleanliness and a better burn; as opposed to tampering with the combustion characteristics of the fuel.

2.1 DOCUMENT SCOPE

The intent of this document scope is to provide technical analysis on Standard Diesel's (Control Colas Tank DSL) lubricity after addition of fuel additive, herein referred to as FCC and FCC-V.

2.2 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ASTM	American Standard Test Method
FCC	Fuel Conditioner Concentrate

2.3 REFERENCES

The references used in this document are:

1. Certificate of Analysis Submission No: 58649 (PO: 3806), 25-Oct-2015 (Att. 1).
2. Diesel Fuel Technical Review, Chevron.
3. Practical Lubrication for Industrial Facilities 2nd Edition, Heinz Bloch.
4. http://www.environment.gov.au/topics/environment-protection/fuel-quality/standards/diesel
5. https://www.dieselnet.com/tech/fuel_diesel_lubricity.php

2.4 ATTACHMENTS

1. Intertek Geotech, Report on Diesel Samples, Submission No: 53173b, 24-Feb-2015.
2. Australia Government Department of Environmental and Energy, Fuel Quality in Australia – Diesel Fuel Quality Standard.

3 LUBRICITY

3.1 DEFINITION

Lubricity: Ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load.

Some moving parts of diesel fuel pumps and injectors are protected from wear by the fuel. Lubricity is ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load. The lubrication mechanism is a combination of hydrodynamic lubrication and boundary lubrication. In hydrodynamic lubrication, a layer of liquid prevents contact between the opposing surfaces. For diesel fuel pumps and injectors, the liquid is the fuel itself and viscosity is the key fuel property. Fuels with higher viscosities will provide better hydrodynamic lubrication. Diesel fuels with viscosities within the ASTM D975 specification range provide adequate hydrodynamic lubrication. Boundary lubrication becomes important when high load and/or low speed have squeezed out much of the liquid that provides hydrodynamic lubrication, leaving small areas of the opposing surfaces in contact. Boundary lubricants are compounds that form a protective anti-wear layer by adhering to the solid surfaces.

3.2 OVERVIEW / SPECIFICATIONS

Description	**Definition**
Lubricity	Ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load.
Test Method	IP 450
Effect of Property on Performance / Significance of Property	Poor lubricity causes excessive wear and at the extreme, causes catastrophic failure.
Upper Limit / Specification	>600 µm might not prevent excessive wear.
Maximum Standard Lubricity	<450 µm should provide sufficient lubricity.

3.3 ANALYSIS

The maximum standard lubricity is 450 µm (Ref. 4) to ensure sufficient lubricity for the engine's operation. Poor lubricity (>600 µm) could potentially causes excessive wear and at the extreme, causes catastrophic failure.

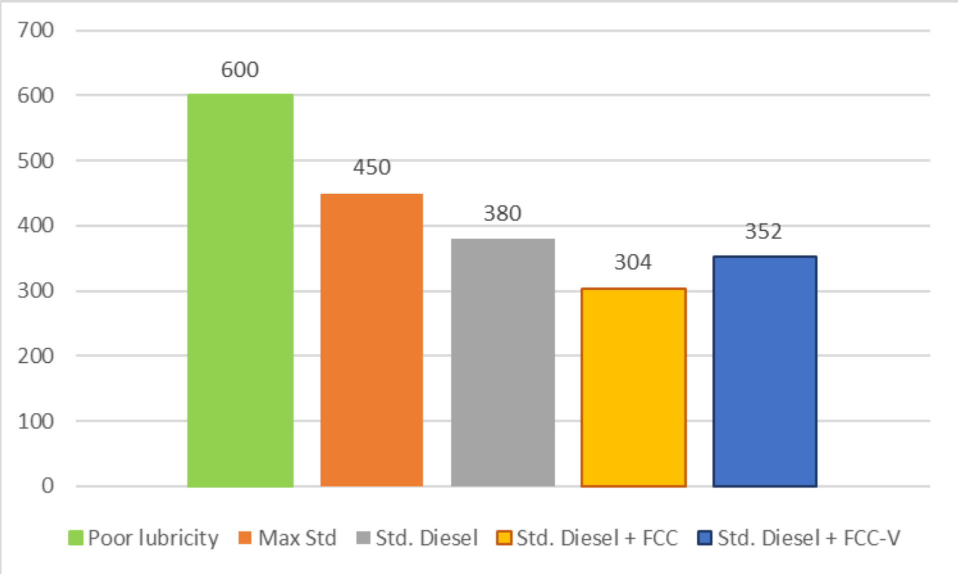
Based on the test results (Att. 1), the standard diesel (Control Colas Tank DSL) lubricity is 380 µm and when the standard diesel is added with:

- FCC: The lubricity improves from 380 µm (standard diesel) to 304 µm. This is a significant **20%** improvement of lubricity on the diesel fuel.
- FCC-V: The lubricity improves from 380 µm (standard diesel) to 352 µm. This is a high **7%** improvement of lubricity on the diesel fuel.

This increase in lubricity for both FCC and FCC-V, particularly FCC, will significantly improve durability of equipment and prevent premature wear of equipment by allowing equipment to operate to its intended design life. The improvement on lubricity is illustrated graphically in Figure 3.1.

The specifications of lubricity (upper limit, maximum standard and control sample) and improvement on lubricity of diesel (control sample) after addition of FCC and FCC-V are illustrated in Figure 3.1 below.

Figure 3.1: Lubricity Specifications (Std. Diesel and with FCC / FCC-V)



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www.intertek.com

CHOICECHEM
27 BOULDER ROAD
MALAGA WA 6090

24-February-2015

Attention: PETER SPRY
Purchase Order no. N/A
Your reference See sample details.
Our Ref No: Submission No: 53173b

REPORT ON DIESEL SAMPLES

Introduction:
Three diesel samples (see sample details) were received 10th February 2015 for testing as requested. The samples were tested as received.

Sample Details:

FCC Lab No: 59309-1

FCC-V Lab No: 59309-2

Control Colas Tank DSL Lab No: 59309-3

Results:

Samples	Test	Unit	Result
FCC	Lubricity IP450	um	304
FCC-V	Lubricity IP450	um	352
Control Colas Tank DSL	Lubricity IP450	um	380

INTERTEKGEOTECH

Noel Mellican
Division Manager

Max Offer
Technical Manager

Sample as received by Intertek. This report is for the exclusive use of Intertek's Client and is provided pursuant to the agreement between Intertek and its Client. Intertek's responsibility and liability are limited to the terms and conditions of the agreement. Intertek assumes no liability to any party, other than to the Client in accordance with the agreement, for any loss, expense or damage occasioned by the use of this report. Only the Client is authorized to permit copying or distribution of this report and then only in its entirety.
The observations and test results in this report are relevant only to the sample tested.

Report Reviewed

Online Services

Australian Government
Department of the Environment and Energy

Diesel fuel quality standard

Management of Diesel Oil Burn Systems

The use of oil burn systems in diesel vehicles can potentially breach section 20 of the *Fuel Quality Standards Act 2000* if the addition of oil to the diesel within the engine results in the diesel not complying with the Fuel Standard (Automotive Diesel) Determination 2001.

As the Australian Government is committed to international best practice regulation of fuel quality, it has been decided not to amend the determination to allow the use of oil burn systems in any diesel vehicles operating in Australia.

It is considered that there is enough concern about the potential impacts on sulfur levels in diesel from the addition of used motor oil to warrant this decision.

Management of Diesel Oil Burn Systems - position paper

Environmental standards

The first suite of national fuel standards, which came into force on 1 January 2002, regulates petrol and diesel parameters that have a direct impact on the environment ('environmental standards').
The standards will have a major impact on the amount of toxic pollutants in vehicle emissions, such as benzene and particles, with studies estimating reductions of up to 50 per cent for some pollutants over 20 years. This is great news for our health, with cleaner air helping to reduce the number of serious respiratory illnesses and asthma cases, particularly in children.

Operability standards

A second suite of national fuel standards came into force on 16 October 2002. These standards ('operability standards') address those parameters of diesel that do not have a direct impact on emissions but, if not controlled, can have adverse impacts on the efficient operation of the engine.

Further operability standards are being developed that may include:

- for diesel - the parameters are appearance, acidity, cloud point and cold filter plugging point.

Summary table

The environmental and operability standards are consolidated in the following tables. The legal instrument implementing the standard is:

Fuel Standard (Automotive Diesel) Determination 2001

Diesel standards

Parameter	National standard	Date of effect	Test Method
Biodiesel [1]	5.0% volume by volume (max)	1-Mar-09	EN 14078
Sulfur	500 ppm (max)	31-Dec-02	ASTM D5453
	50 ppm (max)	1-Jan-06	
	10 ppm (max)	1-Jan-09	
Cetane Index	46 (min) index	1-Jan-02	ASTM D4737
Derived Cetane Number (of diesel containing biodiesel)	51.0 (min)	21-Feb-09	ASTM D6890
Density	820 (min) to 860 (max) kg/m^3	1-Jan-02	ASTM D1298
	820 (min) to 850 (max) kg/m^3	1-Jan-06	
Distillation T95	370°C (max)	1-Jan-02	ASTM D86
	360°C (max)	1-Jan-06	
Polyaromatic hydrocarbons (PAHs)	11% m/m (max)	1-Jan-06	IP391
Ash	100 ppm (max)	1-Jan-02	ASTM D482
Viscosity	2.0 to 4.5 cSt @ 40°C	1-Jan-02	ASTM D445
Carbon Residue (10% distillation residue)	0.2 mass % max	16-Oct-02	ASTM D4530
Water and sediment	0.05 vol % max	16-Oct-02	ASTM D2709
Water (all diesel containing biodiesel)	200 mg/kg (max)	21-Feb-09	ASTM 6304
Conductivity @ ambient temp	50 pS/m (Min) @ambient temp (all diesel held by a terminal or refinery for sale or distribution)	16-Oct-02	ASTM D2624
Oxidation Stability	25 mg/L max	16-Oct-02	ASTM D2274
Colour	2 max	16-Oct-02	ASTM D1500
Copper Corrosion (3 hrs @ 50°C)	Class 1 max	16-Oct-02	ASTM D130

Flash point	61.5°C min	16-Oct-02	ASTM D93
Filter blocking tendency	2.0 max	16-Oct-02	IP 387
Lubricity	0.460 mm (max) (all diesel containing less than 500 ppm sulfur)	16-Oct-02	IP 450

[1] The biodiesel component of diesel must meet the requirements of fuel quality standard for biodiesel set out in the Fuel Standard (Biodiesel) Determination 2003.

Disclaimer

The information contained on this page is of a general nature only and should be read in conjunction with the *Fuel Quality Standards Act 2000*, Fuel Quality Standards Regulations 2001 and the Fuel Standard (Automotive Diesel) Determination 2001. Fuel suppliers may wish to seek legal advice about their obligations under this legislation.

Revision A

Standard Diesel & FCC Additive Technical Analysis

ADDF-REP-TA-0001

Michelle Lam

STANDARD DIESEL & FCC ADDITIVE TECHNICAL ANALYSIS

ADDF-REP-TA-0001

Revision Number: A
Revision Date: 12/12/2016

PREPARED BY

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Michelle Lam	Senior Chemical / Process Engineer (Chartered Professional Engineer Engineering Council UK (CEng) Reg. No. 594288, MIChemE No. 99887878)		14/12/2016

REVIEWED BY

Name	Designation	Signature	Date
Justin West	Australasian Business Development Manager		

Approved by

Name	Designation	Signature	Date

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1 EXECUTIVE SUMMARY

Fuel Conditioner Concentrate (FCC) is added directly to fuel storage tanks to eliminate the problems associated with water contamination. FCC ensures that vehicle fuel systems remain clean and free from corrosion, gums, and varnishes. The main benefit of the FCC is derived from its regular use to maintain fuel systems free from liquid water. This prevents biological activity, reduces corrosion and inhibits reaction of the fuel with water. Regular use of FCC ensures that carburetors and fuel injectors work at peak performance eliminating poor running problems and expensive maintenance. The benefits of FCC extend throughout the fuel system.

Key summary based on the technical analysis of the Standard Diesel spiked with FCC improves and enhances the diesel fuel properties in categories below:

Safety

- FCC does not impact the hazard level classification of the fuel which determines and affects the storage and handling fuel. With a low moderate hazard level fuel, the classification and hazard level remains unchanged with addition of FCC (minimal change in Flash Point).

Environmental

- FCC reduces hydrocarbon and Carbon Monoxide (CO) emissions (increase in T95)
- FCC reduces white smoke on startup, and reduce NOx (Nitrogen Oxide) and Particulate Matter (PM) emissions (Increase in Cetane Index)
- FCC decreases density in fuel which:
  - Reduces the NOx emission and results in large decrease in PM for high emission emitting engine (heavy duty diesel emissions),
  - Results in relatively large decrease in PM for both Direct and Indirect Injection Engines for current light duty diesel vehicle.

Combustion, Fuel Efficiency

- FCC improves fuel combustion (Increase in Cetane Index)

Performance, Maintenance

- FCC improves lubricity by 3.8% which improves durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.
- FCC maintains this important characteristic of the fuel for Filter Blocking Tendency (FBT) which affects performance and lifetime of the engine.

2 INTRODUCTION

FCC is an innovative and scientifically proven blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's engines. It's a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency. It is suitable for use for a large variety of fuel types.

With FCC, improvements in fuel efficiency and savings in maintenance costs are achieved through cleanliness and a better burn; as opposed to tampering with the combustion characteristics of the fuel.

2.1 BACKGROUND

FCC is a blend of blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's high performance engines. The Primary benefits of FCC are:

- Solubilises liquid water into the fuel.
- Reduces or eliminates the conditions favourable to the growth of microorganisms.
- Stabilises fuel by inhibiting the formation of gums and varnish.
- Inhibits corrosion of fuel system components.
- Promotes a uniform fuel spray pattern in combustion chambers, thus reducing carbonisation and improving combustion efficiency.
- Inhibits formation of corrosive acids in combustion chambers.

2.2 DOCUMENT SCOPE

The intent of this document scope is to provide technical analysis on Standard Diesel (fuel quality within specification) properties after addition of fuel additive, herein referred to as FCC (spiked with ratio of 1:4000). Analysis is made in comparison to Standard Diesel (control sample) and the properties assessed (based on Certificate of Analysis – Attachment 1) are:

- Flash Point,
- Filter Blocking Tendency,
- Lubricity,
- Cetane Index,
- Density and
- Distillation T95.

2.3 SPECIFICATION OF CLEAN FUEL

Clean fuels are fuels that contain very few of components that may harm the environment, like sulphur, nitrogen, and organometallic compounds (Benzene can also be included along with polycyclic aromatic hydrocarbons (PAH)).

The key specification for diesel as summarised in Table 2.1 and Table 2.2 below:

Table 2.1: Key Specification / Parameter for Diesel

Specification	Euro 2000	Euro 2005	USA 2005	Canada 2005	Australia
Sulphur max (wppm)	50	50	15	50	10
Density (kg/m³)	820 – 845	820 – 845	840	N/A	820 – 860
Cetane Number	> 51	> 51	> 51	> 51	48
PAH (wt%)	< 11	N/A	11	N/A	11
T95 (°C)	< 360	N/A	N/A	N/A	360

Table 2.2: Key Specification / Parameter for Diesel in the ASEAN Region

Specification	Malaysia	Thailand	Singapore	Indonesia	Philippines	Vietnam
Sulphur max (wt%)	0.05	0.05	0.5	0.5	0.5	0.3
Density (kg/m³)	N/A	820 – 890	860 (max)	820 – 870	N/A	860 (max)
Cetane Number	50	N/A	N/A	45	N/A	N/A
PAH (wt%)	N/A	N/A	N/A	N/A	N/A	N/A
T90 (°C)	370	338	370	N/A	N/A	370
T95 (°C)	N/A	N/A	N/A	N/A	N/A	N/A

3 ABBREVIATIONS & DEFINITIONS

3.1 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ASTM	American Standard Test Method
CO	Carbon Monoxide
CN	Cetane Number
FBT	Filter Blocking Tendency
FCC	Fuel Conditioner Concentrate
IEC	International Electrotechnical Commission
IP	International Protection
ISO	International Organization for Standardization
NATA	National Association of Testing Authorities, Australia
NOx	Nitrogen Oxide
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter

3.2 DEFINITIONS

The property's definitions are summarised as below:

Property	Definition
Flash Point	The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.
Filter Blocking Tendency	FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter.
Lubricity	Ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load.
Cetane Index	Measures the performance / quality of a fuel in a diesel engine by its ability for auto-ignition.
Density	Characteristics of a substance indicated as Mass per unit volume varies with temperature and pressure. This variation is typically small for solids and liquids but much greater for gases.
Distillation T95	Temperature at which 95% of diesel evaporates.

3.3 REFERENCES

The references used in this document are:

1. Certificate of Analysis Submission No: 58649 (PO: 3806), 25-Oct-2015 (Att. 1).
2. Dictionary of Chemical Engineering, Schaschke, Carl (ISBN 978-0-19-965145-0)
3. http://www.engineeringtoolbox.com/flash-point-fuels-d_937.html
4. Gasoline, Diesel and Ethanol Biofuels from Grasses and Plants,1st Edition, Ram B. Gupta, Ayhan Demirbas.
5. Diesel Fuel Technical Review, Chevron.
6. Practical Lubrication for Industrial Facilities 2nd Edition, Heinz Bloch.
7. The Significance of Test of Petroleum Products, 7th edition, Salvatore J. Rand.
8. Fundamentals of Petroleum Refining, 2010, Fahim, Mohamed A.; Alsahhaf, Taher A.; Elkilani, Amal.
9. Policy Guidelines for Reducing Vehicle Emissions in ASIA.
10. Lee, Robert, Hobbs, Christine H., and Pedley, Joanna F.: "Fuel Quality Impact on Heavy Duty Diesel Emissions: A Literature Review," Document Number 982649, SAE Technical Papers, http://www.sae.org/technical/papers/982649/
11. http://www.environment.gov.au/topics/environment-protection/fuel-quality/standards/diesel
12. https://www.dieselnet.com/tech/fuel_diesel_lubricity.php

3.4 ATTACHMENTS

1. Intertek Geotech, Certificate of Analysis Submission No: 58649 (PO: 3806), 25-Oct-2015.
2. Australia Government Department of Environmental and Energy, Fuel Quality in Australia – Diesel Fuel Quality Standard.

4 PROPERTY OF DIESEL

4.1 FLASH POINT

4.1.1 DEFINITION

The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure. The rapid combustion occurs in the form of momentary flash point. Flash point data is important for the safe storage and transportation of volatile liquids. Flash Point for typical Diesel and Fuel Oils are tabulated in Table 4.1 below:

Table 4.1: Flash Point for Diesel / Fuel Oils

Fuel	Flash Point (°C)
Standard Diesel	71.00 (Att. 1)
Standard Diesel + FCC	67.00 (Att. 1)
Biodiesel	130.00
Diesel Fuel (1-D)	37.78
Diesel Fuel (2-D)	52.22
Diesel Fuel (4-D)	54.44
Fuels Oil No.1	37.78 – 72.22
Fuels Oil No.2	52.22 – 95.56
Fuels Oil No.4	61.11 – 115.56
Fuels Oil No.5 Lite	68.89 – 168.89
Fuels Oil No.5 Heavy	71.11 – 121.11

4.1.2 ANALYSIS

A low flash point is a high fire hazard. The minimum Flash Point is 52°C based on ASTM D975 requirements for Diesel Fuel Oils (Ref. 5) and 61.5°C based on ASTM D93 (Ref. 11) for safe storage and handling of diesel.

Standard Diesel (control sample – Attachment 1) Flash Point is 71°C (Fuel Oil No. 1 – 5) and with addition of FCC, the Flash Point is slightly lowered to 67°C, which is within the moderate low hazard level classification. Hence, addition of FCC does not greatly impact on Flash Point of the diesel and the storage and handling of the fluid. Flash Point Hazard Level classification is summarised in Table 4.2 below:

Table 4.2: Hazard Level Classification based on Flash Point

Hazard Level	Flash Point (°C)
Very low hazard	> 93
Moderate low hazard	66 to 93
High to Moderate Hazard	38 to 66
Extremely High to High Hazard	-18 to 38
Extreme Hazard	< -18

4.2 FILTER BLOCKING TENDENCY

4.2.1 DEFINITION

FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter. Unstable diesel fuels can form soluble gums or insoluble organic particulates. Both gums and particulates may contribute to injector deposits, and particulates can clog fuel filters. The formation of gums and particulates may occur gradually during long-term storage or quickly during fuel system recirculation caused by fuel heating. Sometimes a combination of fuel behaviour and fuel system design can cause filter plugging.

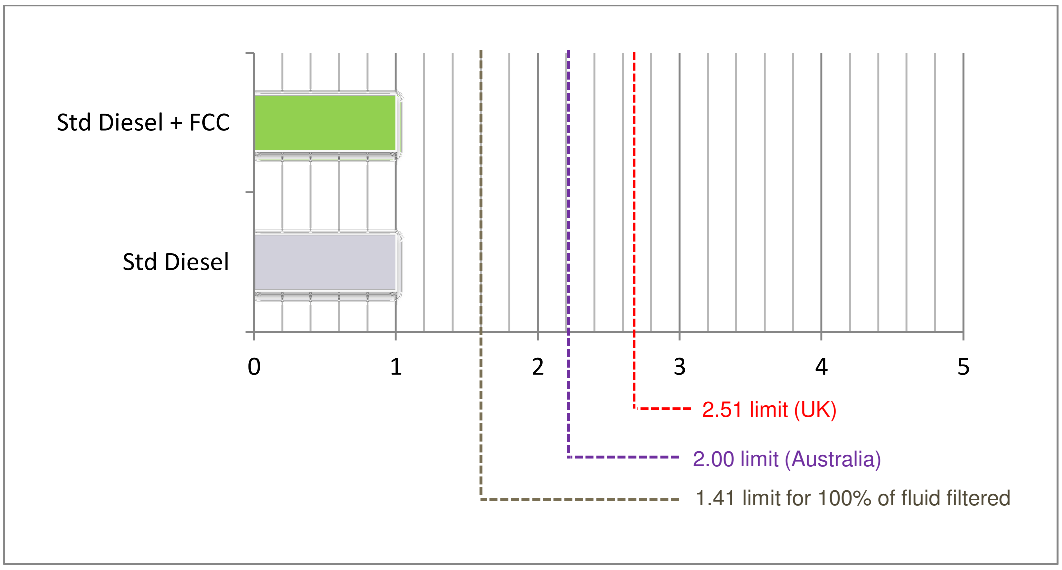
4.2.2 ANALYSIS

Based on the test results, there is no change in FBT after addition of FCC as the Standard Diesel used as control sample has a low FBT. This low FBT of Standard Diesel (control sample) and Standard Diesel + FCC is 1.00, which is below 1.41, which means all of the volume 100% of flow could be filtered. This indicates that FCC maintains this important characteristic of the fuel for FBT which affects performance and lifetime of the engine.

The FBT limits are detailed below and illustrated in Figure 4.1:

- FBT values exceeded 1.41 indicates that not all of the volume could be filtered.
- Australia FBT limit value of 2.0 for Diesel fuels (Ref. 11).
- United Kingdom FBT limit < 2.51 (UK EN590 Specifications).

Figure 4.1: FBT (Diesel Specifications)



4.3 LUBRICITY

4.3.1 DEFINITION

Some moving parts of diesel fuel pumps and injectors are protected from wear by the fuel. Lubricity is ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load. The lubrication mechanism is a combination of hydrodynamic lubrication and boundary lubrication. In hydrodynamic lubrication, a layer of liquid prevents contact between the opposing surfaces. For diesel fuel pumps and injectors, the liquid is the fuel itself and viscosity is the key fuel property. Fuels with higher viscosities will provide better hydrodynamic lubrication. Diesel fuels with viscosities within the ASTM D975 specification range provide adequate hydrodynamic lubrication. Boundary lubrication becomes important when high load and/or low speed have squeezed out much of the liquid that provides hydrodynamic lubrication, leaving small areas of the opposing surfaces in contact. Boundary lubricants are compounds that form a protective anti-wear layer by adhering to the solid surfaces.

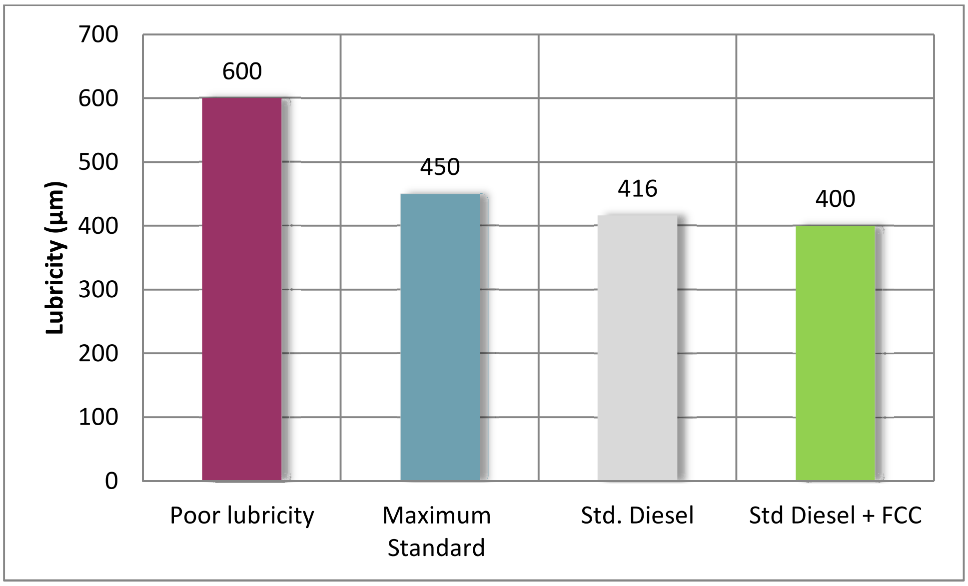
4.3.2 ANALYSIS

The maximum standard lubricity is 450 µm (Ref. 11) to ensure sufficient lubricity for the engine's operation. Poor lubricity (>600 µm) could potentially causes excessive wear and at the extreme, causes catastrophic failure.

The lubricity improves by 3.8% with addition of FCC from 416 µm to 400 µm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.

The specification of lubricity as illustrated in Figure 4.2 below.

Figure 4.2: Lubricity (Diesel Specifications)



4.4 CETANE INDEX

4.4.1 DEFINITION

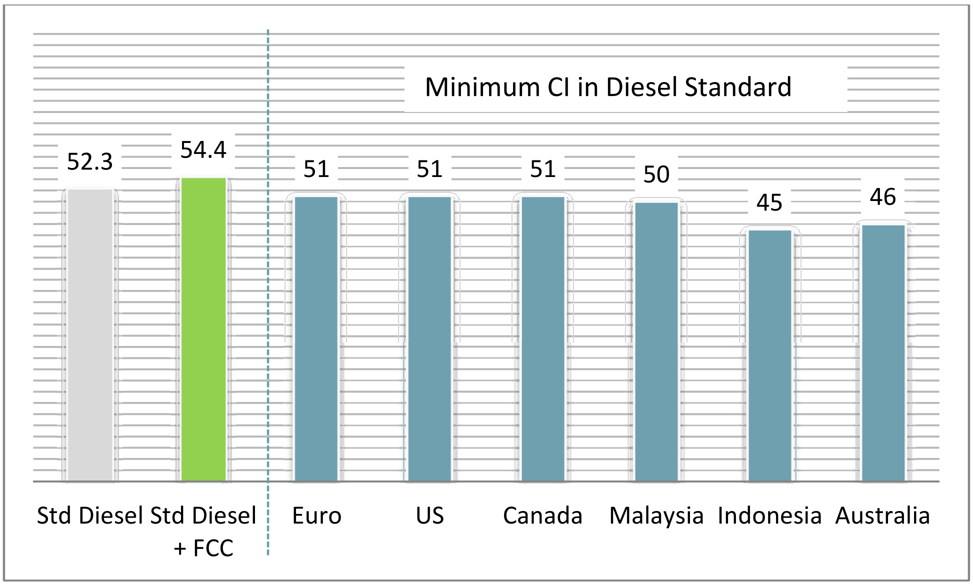
The quality of diesel fuels can be expressed as cetane number or cetane index. The cetane number (CN) is expressed in terms of the volume % of cetane (($C_{16}H_{34}$) which has high ignition (CN = 100)) in a mixture with alpha-methyl-naphthalene (($C_{11}H_{10}$) which has low ignition quality (CN = 0)) that has the same ignition characteristics as a diesel fuel being tested in a standard diesel engine. It is therefore, an indication of ease of self or auto-ignition characteristic of a fuel. The cetane index (CI) is a number calculated from the average boiling point and density of a petroleum fraction in the diesel fuel boiling range, which then estimates the CN of the fraction.

4.4.2 ANALYSIS

Based on the laboratory analysis by Intertek (Attachment 1), addition of FCC has improved the CI by 4% from 52.3 to 54.4. The increase of CI on the fuel increase the ease of self-ignition of the fuel and therefore enables engine to operate more effectively and improves engine performance.

The specification of CI range from 45 to 51 and as illustrated in Figure 4.3 below.

Figure 4.3: Cetane Index (Diesel Specifications)



Increasing the cetane number improves fuel combustion, reduces white smoke on startup, and tends to reduce NOx and PM emissions. NOx seems to be reduced in all engines, while PM reductions are engine-dependent. For high speed diesel engine, high CI fuels are desirable as engine performance improvement on the high speed engine is evident in comparison using low CI fuels.

4.5 DENSITY

4.5.1 DEFINITION

Characteristics of a substance indicated as mass per unit volume varies with temperature and pressure. This variation is typically small for solids and liquids (non-compressible) but much greater for gases (compressible). Non compressible liquids / solids have relatively higher density than gas.

4.5.2 ANALYSIS

Changes in fuel density affect the energy content of the fuel brought into the engine at a given injector setting. Reducing fuel density tends to decrease NOx emissions in older technology engines that cannot compensate for this change. Emissions from modern engines, with electronic injection and computer control, are not influenced by the density of the fuel.

The density of diesel specification is from 820 (min) to 850 (max) kg/m³ (Ref. 11). Standard Density (control sample) is 838.2 kg/m³ and with addition of FCC, the density is reduced by 0.6% to 833.2 kg/m³.

For heavy duty diesel emissions, the decrease in density with FCC has a favourable impact on NOx and PM as this will reduce the NOx emission and a relatively large decrease in PM for high emission emitting engine (no effect on low emission emitting engine).

For current light duty diesel vehicle, decrease in density (828 - 855 kg/m³) will have a relatively large decrease in PM for both Direct and Indirect Injection Engines. However, for NOx emissions, a decrease in density has no impact on Indirect Injection Engines and a small increase in NOx for Direct Injection Engines.

4.6 DISTILLATION

4.6.1 DEFINITION

T95 is the temperature at which 95 percent of a particular diesel fuel distils in a standardized distillation test (ASTM D86). It is an indirect measure of volatility of the fluid where the T95 temperature is where 95% of the fluid (i.e. diesel) is vapourised and only 5% remain in liquid state. Lower T95 indicates a more volatile fluid and where 95% of the fluid vapourises at a lower temperature.

4.6.2 ANALYSIS

The maximum limit of T95 temperature for diesel specification is 360°C (Ref. 11).

From the Intertek analysis (Attachment 1), T95 increases from 337.7°C to 344.9°C which is still below the specification at 360°C. The increase in T95 reduces hydrocarbon and CO emissions but increases NOx emissions slightly. PM emissions are unaffected.

5 SUMMARY

Property	**Definition**	**Test Method**	**Effect of Property on Performance / Significance of Property**	**Limits / Specifications**	**Required Specification**	**Standard Diesel + FCC**
Flash Point	The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.	ASTM D93	Indication of fire and explosion hazard which is important for the safe storage and transportation of volatile liquids. A low flash point is a high fire hazard.	• Very low hazard > 93℃ • Moderate low hazard 66 to 93℃ • High to Moderate Hazard 38 to 66℃ • Extremely High to High Hazard -18 to 38℃ • Extreme Hazard < -18℃	51℃ (min)	67℃ (5.6% reduction from 71℃).
Filter Blocking Tendency	FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter.	IP 387 (Procedure A)	At low temperatures below the cloud point of diesel fuel, wax precipitates from fuel and can cause filter blocking and affecting quality of fuel.	If values exceeded 1.41 not all of the volume could be filtered. Limit < 2.51 (UK EN590 Specifications).	< 1.41	1.00 – No change / impact.
Lubricity	Ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load.	IP 450	Poor lubricity causes excessive wear and at the extreme, causes catastrophic failure.	>600 µm might not prevent excessive wear <450 µm should provide sufficient lubricity	<450 µm	400 µm (3.8% reduction / improvement from 416 µm)

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	Required Specification	Standard Diesel + FCC
Cetane Index	Measures the performance / quality of a fuel in a diesel engine by its ability for auto-ignition.	ASTM D4737	Increase in Cetane will reduce emission of NOx [a]. High speed diesel engine operates more effectively with high CI fuels.	• CI of 45 (Diesel No. 1) is used in high speed engines, trucks and buses. • CI of 40 (Diesel No. 2). • CN = 30 is used as Railroad diesel fuels (similar to the heavier automotive diesel fuels, but have higher boiling ranges up to 400℃.	40 (min)	54.4 (4% increase from 52.3).
Density	Characteristics of a substance indicated as Mass per unit volume varies with temperature and pressure.	ASTM 4052	Affects heating value and hence fuel economy. Density to be used in equation along with Heating Value to determine Heat of Combustion which consequently affects engine performance. Reduction in density will reduce NOx emissions [a].	Range from 820 – 890 kg/m³ depending on country / location.	820 – 890 kg/m³	833.2 kg/m³ (0.6% decrease from 838.2 kg/m³)
Distillation T95	Temperature at which 95% of diesel evaporates.	ASTM D86	Reduction of T95 will marginally reduce NOx emissions [a] and a relatively large reduction of particulates (PM) emission [a] [b].	Maximum temperature of 360℃.	360℃ (max)	344.9℃ (2.1% increase from 337.7℃).

(a) For heavy duty diesel emissions.
(b) High emissions emitting engine

Key summary based on the technical analysis of the Standard Diesel spiked with FCC on a comparative basis to Standard Diesel:

1. Flash Point: Marginal decrease with no change in classification of hazard level (moderate low hazard). Hence, addition of FCC does not greatly impact on Flash Point of the diesel and the storage and handling of the fluid.
2. No change in FBT. FCC maintains this important characteristic of the fuel for FBT which affects performance and lifetime of the engine.
3. **Lubricity:** Improves by 3.8% with addition of FCC from 416 µm to 400 µm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.
4. **Cetane Index:** Increasing the cetane number improves fuel combustion, reduces white smoke on startup, and tends to reduce NOx and PM emissions.
5. **Density:** For heavy duty diesel emissions, the decrease in density with FCC has a favourable impact on NOx and PM as this will reduce the NOx emission and a relatively large decrease in PM for high emission emitting engine (no effect on low emission emitting engine).
   For current light duty diesel vehicle, decrease in density relatively large decrease in PM for both Direct and Indirect Injection Engines. However, for NOx emissions, a decrease in density has no impact on Indirect Injection Engines and a small increase in NOx for Direct Injection Engines.
6. T95: Marginal increases from 337.7℃ to 344.9℃ which is still below the specification at 360℃. The increase in T95 reduces hydrocarbon and CO emissions but increases NOx emissions slightly. PM emissions are unaffected.

Attachment 1

Intertek GEOTECH

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www.intertek.com

ChoiceChem
27 Boulder Road
Malaga WA 6090

25-October-2016

Attention: Peter Spry
Purchase Order no. 3806
Your reference Standard Diesel and Additives
Our Ref No: Submission No: 58649

CERTIFICATE OF ANALYSIS

Introduction:

A sealed can of Standard Diesel and an additives bottle were received on 12 October 2016. The Standard Diesel was divided in two portion.The first portion was spiked with the additives with a ratio of 1:4000, spike:Diesel and the second portion was considered as the control sample. Both samples were tested as per client request and they were labelled as follows:

Standard Diesel Lab No: 326771
Standard Diesel + Additives Lab No: 326776

Method of Analysis & Testing:
The analysis was carried our according to quote CRQU051016Rev.

Results:

Property	Test Method	Unit	Standard Diesel	Standard Diesel + Additives
Flash Point	ASTM D93	°C	71.0	67.0
Filter blocking tendency/ Procedure A	IP 387	unit	1.00	1.00
Lubricity	IP 450	µm	416	400
Cetane Index	ASTM D4737	unit	52.3	54.4
Density	ASTM 4052	kg/L	0.8382	0.8332
Distillation T95	ASTM D86	°C	337.7	344.9

The analysis results denoted by are part of the laboratory NATA accreditation 13658. Accredited for compliance with ISO/IEC 17025

Chetna Ragoo
Industrial Chemist

NATA
WORLD RECOGNISED ACCREDITATION

Report enquiries to: Industrial Chemist

Report Reviewed

Attachment 2

Online Services

Australian Government
Department of the Environment and Energy

Diesel fuel quality standard

Management of Diesel Oil Burn Systems

The use of oil burn systems in diesel vehicles can potentially breach section 20 of the *Fuel Quality Standards Act 2000* if the addition of oil to the diesel within the engine results in the diesel not complying with the Fuel Standard (Automotive Diesel) Determination 2001.

As the Australian Government is committed to international best practice regulation of fuel quality, it has been decided not to amend the determination to allow the use of oil burn systems in any diesel vehicles operating in Australia.

It is considered that there is enough concern about the potential impacts on sulfur levels in diesel from the addition of used motor oil to warrant this decision.

Management of Diesel Oil Burn Systems - position paper

Environmental standards

The first suite of national fuel standards, which came into force on 1 January 2002, regulates petrol and diesel parameters that have a direct impact on the environment ('environmental standards').
The standards will have a major impact on the amount of toxic pollutants in vehicle emissions, such as benzene and particles, with studies estimating reductions of up to 50 per cent for some pollutants over 20 years. This is great news for our health, with cleaner air helping to reduce the number of serious respiratory illnesses and asthma cases, particularly in children.

Operability standards

A second suite of national fuel standards came into force on 16 October 2002. These standards ('operability standards') address those parameters of diesel that do not have a direct impact on emissions but, if not controlled, can have adverse impacts on the efficient operation of the engine.

Further operability standards are being developed that may include:

- for diesel - the parameters are appearance, acidity, cloud point and cold filter plugging point.

Summary table

The environmental and operability standards are consolidated in the following tables. The legal instrument implementing the standard is:

Fuel Standard (Automotive Diesel) Determination 2001

Diesel standards

Parameter	National standard	Date of effect	Test Method
Biodiesel [1]	5.0% volume by volume (max)	1-Mar-09	EN 14078
Sulfur	500 ppm (max)	31-Dec-02	ASTM D5453
	50 ppm (max)	1-Jan-06	
	10 ppm (max)	1-Jan-09	
Cetane Index	46 (min) index	1-Jan-02	ASTM D4737
Derived Cetane Number (of diesel containing biodiesel)	51.0 (min)	21-Feb-09	ASTM D6890
Density	820 (min) to 860 (max) kg/m^3	1-Jan-02	ASTM D1298
	820 (min) to 850 (max) kg/m^3	1-Jan-06	
Distillation T95	370°C (max)	1-Jan-02	ASTM D86
	360°C (max)	1-Jan-06	
Polyaromatic hydrocarbons (PAHs)	11% m/m (max)	1-Jan-06	IP391
Ash	100 ppm (max)	1-Jan-02	ASTM D482
Viscosity	2.0 to 4.5 cSt @ 40°C	1-Jan-02	ASTM D445
Carbon Residue (10% distillation residue)	0.2 mass % max	16-Oct-02	ASTM D4530
Water and sediment	0.05 vol % max	16-Oct-02	ASTM D2709
Water (all diesel containing biodiesel)	200 mg/kg (max)	21-Feb-09	ASTM 6304
Conductivity @ ambient temp	50 pS/m (Min) @ambient temp (all diesel held by a terminal or refinery for sale or distribution)	16-Oct-02	ASTM D2624
Oxidation Stability	25 mg/L max	16-Oct-02	ASTM D2274
Colour	2 max	16-Oct-02	ASTM D1500
Copper Corrosion (3 hrs @ 50°C)	Class 1 max	16-Oct-02	ASTM D130

Attachment 2

Flash point	61.5°C min	16-Oct-02	ASTM D93
Filter blocking tendency	2.0 max	16-Oct-02	IP 387
Lubricity	0.460 mm (max) (all diesel containing less than 500 ppm sulfur)	16-Oct-02	IP 450

[1] The biodiesel component of diesel must meet the requirements of fuel quality standard for biodiesel set out in the Fuel Standard (Biodiesel) Determination 2003.

Disclaimer

The information contained on this page is of a general nature only and should be read in conjunction with the *Fuel Quality Standards Act 2000*, Fuel Quality Standards Regulations 2001 and the Fuel Standard (Automotive Diesel) Determination 2001. Fuel suppliers may wish to seek legal advice about their obligations under this legislation.

Revision A

Standard Petrol & FCC Additive Technical Analysis on Wear Scar Diameter

ADDF-REP-TA-0003

Michelle Lam

STANDARD PETROL & FCC ADDITIVE TECHNICAL ANALYSIS ON WEAR SCAR DIAMETER

ADDF-REP-TA-0003

Revision Number: A
Revision Date: 9/02/2017

PREPARED BY

Name	Designation	Signature	Date
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REVIEWED BY

Name	Designation	Signature	Date
Justin West	Australasian Business Development Manager		

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1 EXECUTIVE SUMMARY

Fuel Conditioner Concentrate (FCC) is added directly to fuel storage tanks to eliminate the problems associated with water contamination. FCC ensures that vehicle fuel systems remain clean and free from corrosion, gums, and varnishes. The main benefit of the FCC is derived from its regular use to maintain fuel systems free from liquid water. This prevents biological activity, reduces corrosion and inhibits reaction of the fuel with water. Regular use of FCC ensures that carburetors and fuel injectors work at peak performance eliminating poor running problems and expensive maintenance. The benefits of FCC extend throughout the fuel system.

Addition of FCC reduces the Wear Scar Diameter from 685 µm to 200 µm which is a significant **71%** improvement of lubricity on the petrol fuel. The wear scar diameter is a measure of lubricity of fluid which is the ability of fluid or compound (in this case petrol fuel) to act as a lubricant to minimize friction and damage to surfaces in contact under relative motion load. The smaller the scar, the less wear has occurred and hence the better the lubricity of the fuel. Hence this significant reduction of wear scar diameter which is improvement of lubricity of the fuel will greatly increase durability of equipment which prevents premature wear of equipment and allowing equipment to operate to its intended design life. This increase in lubricity directly improves engine’s performance and minimises maintenance requirement.

2 INTRODUCTION

FCC is an innovative and scientifically proven blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's engines. It's a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency. It is suitable for use for a large variety of fuel types.

With FCC, improvements in fuel efficiency and savings in maintenance costs are achieved through cleanliness and a better burn; as opposed to tampering with the combustion characteristics of the fuel.

2.1 DOCUMENT SCOPE

The intent of this document scope is to provide technical analysis on Standard Petrol's property i.e. wear scar diameter after addition of fuel additive (spiked with ratio of 1:4000), herein referred to as FCC.

2.2 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ASTM	American Standard Test Method
FCC	Fuel Conditioner Concentrate
HFRR	High Frequency Reciprocating Rig
WSD	Wear Scar Diameter

2.3 REFERENCES

The references used in this document are:

1. Report of Analysis Laboratory Report ID: 2279679, Sample ID: 2016-PTAD-000126-001, 26-Feb-2016 (Att. 1).
2. Diesel Fuel Technical Review, Chevron.
3. Practical Lubrication for Industrial Facilities 2nd Edition, Heinz Bloch.
4. http://www.environment.gov.au/topics/environment-protection/fuel-quality/standards/diesel
5. https://www.dieselnet.com/tech/fuel_diesel_lubricity.php
6. http://www.fuelcenter.rwth-aachen.de/fileadmin/user_upload/Bilder_und_pdf/Z_TMFB/Veranstaltungen/2TMFB/Presentations/IRF3_2_Fatemi_presentation.pdf

2.4 ATTACHMENTS

1. Intertek Geotech, Report of Analysis Laboratory Report ID: 2279679, Sample ID: 2016-PTAD-000126-001, 26-Feb-2016.
2. Australia Government Department of Environmental and Energy, Fuel Quality in Australia – Diesel Fuel Quality Standard.

3 WEAR SCAR DIAMETER

3.1 DEFINITION

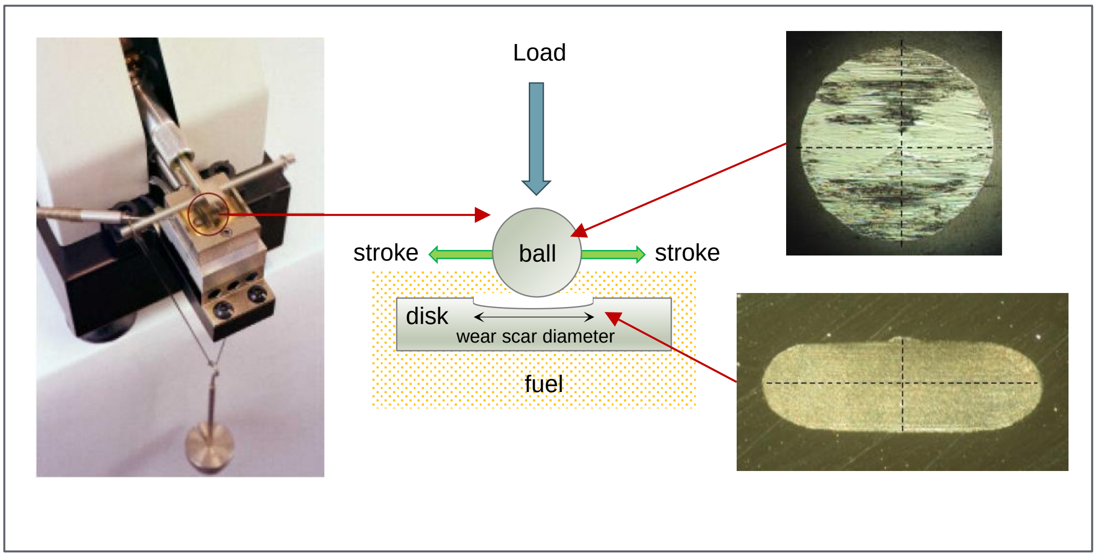
Wear Scar Diameter is a measure of lubricity of fluid which is the ability of fluid or compound (in this case petrol fuel) to act as a lubricant to minimize friction and damage to surfaces in contact under relative motion load.

Some moving parts of petrol fuel pumps and injectors are protected from wear by the fuel. Lubricity is ability of a lubricant (in this case petrol fuel) to minimize friction between and damage to surfaces in relative motion under load. The lubrication mechanism is a combination of hydrodynamic lubrication and boundary lubrication. In hydrodynamic lubrication, a layer of liquid prevents contact between the opposing surfaces. For petrol fuel pumps and injectors, the liquid is the fuel itself and viscosity is the key fuel property. Fuels with higher viscosities will provide better hydrodynamic lubrication. Petrol fuels with viscosities within the ASTM D975 specification range provide adequate hydrodynamic lubrication. Boundary lubrication becomes important when high load and/or low speed have squeezed out much of the liquid that provides hydrodynamic lubrication, leaving small areas of the opposing surfaces in contact. Boundary lubricants are compounds that form a protective anti-wear layer by adhering to the solid surfaces.

3.2 TEST METHOD

That standard petrol and petrol with FCC additive are tested using IP 450 method “HFRR” (high frequency reciprocating rig) method. The test is conducted by placing a hardened steel ball against a hardened steel disk with a load applied to create a certain force between the two surfaces. The fuel sample being tested is poured into a cup that contains these steel samples, and a motor is turned on to force the ball to scour on the surface back and forth motion at a certain rate over a certain distance for 90 minutes. Under a microscope, the width and length of the “wear scar” produced by the scouring motion of the ball is measured. The average of these two dimensions is the “wear scar diameter.” The smaller the scar, the less wear has occurred and hence the better the lubricity of the fuel sample.

Figure 3.1: High Frequency Reciprocating Rig (HFRR) Test



3.3 OVERVIEW / SPECIFICATIONS

Description	Definition
Lubricity	Ability of a lubricant (in this case petrol fuel) to minimize friction between and damage to surfaces in relative motion under load.
Wear Scar Diameter	Measure of length/diameter of "wear scar" as a result of friction wear from the ball and disk in contact immersed in lubricant (HFRR test). The WSD indicates lubricity of the fluid.
Test Method	IP 450
Effect of Property on Performance / Significance of Property	Poor lubricity causes excessive wear and at the extreme, causes catastrophic failure of engine.
Upper Limit / Specification	>600 µm might not prevent excessive wear.
Maximum Standard Lubricity	<450 µm should provide sufficient lubricity.

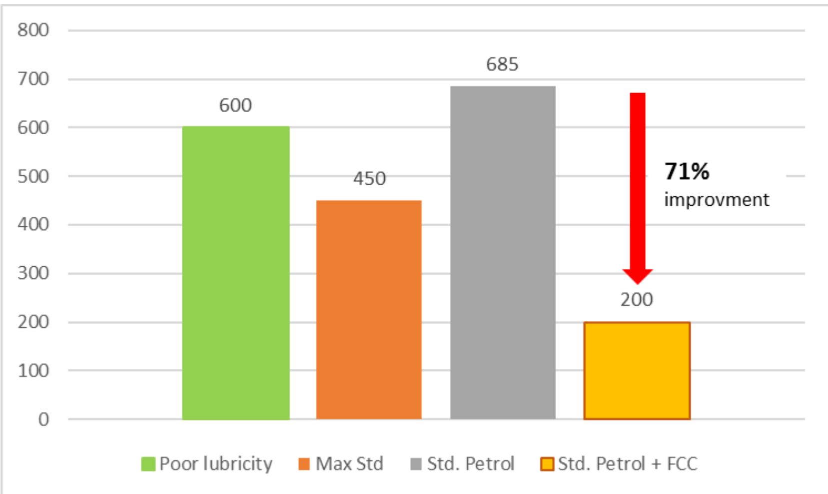
3.4 ANALYSIS

The maximum standard lubricity is 450 µm (Ref. 4) as per Australia fuel specification to ensure sufficient lubricity for the engine's operation. Poor lubricity (>600 µm) could potentially causes excessive wear and at the extreme, causes catastrophic failure.

Based on the test results (Att. 1), the standard petrol wear scar diameter is 685 µm. When the standard petrol is added with FCC, the wear scar diameter is drastically reduced to only 200 µm. The lubricity of the fuel after addition of FCC improves from 685 µm (standard petrol) to 200 µm which is a significant **71%** improvement of lubricity on the petrol fuel.

This increase in lubricity for FCC, will significantly improve durability of equipment and prevent premature wear of equipment by allowing equipment to operate to its intended design life. The improvement on lubricity is illustrated graphically in Figure 3.2 with the specifications of lubricity (upper limit, maximum standard and control sample).

Figure 3.2: Lubricity Specifications (Std. Petrol and with FCC)



Intertek

Report of Analysis

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Laboratory Report ID : 2279679
Job No. : 2016-PTAD-000126
Client Reference : Not Supplied

Sample ID	: 2016-PTAD-000126-001	**Date Taken**	: Not Supplied
Sample Designated as	: E10	**Date Submitted**	: 24-Feb-2016
Sampling Point	: Not Supplied	**Date Tested**	: 26-Feb-2016
Job Location	: Adelaide, SA	**Drawn By**	: Client
Representing	: Petrol with additive added in dilution ration of 1:4000		

Method		Test	Result	Units
IP 450 - modified		Corrected Mean Wear Scar Diameter	200	µm
ASTM D2699	j	Research O.N.	91.4	

Sample Received Condition : Good (No Seal)
Seal Number : Not Applicable
Sampling Method : Not Applicable
Remarks : Method IP 450 was modified as the sample type was outside the scope of the test method and the test temperature was 25C. Therefore results should be considered indicative only.

Sample ID	: 2016-PTAD-000126-003	**Date Taken**	: Not Supplied
Sample Designated as	: E10	**Date Submitted**	: 24-Feb-2016
Sampling Point	: Not Supplied	**Date Tested**	: 01-Mar-2016
Job Location	: Adelaide, SA	**Drawn By**	: Client
Representing	: E10 Petrol with no additive		

Method	Test	Result	Units
IP 450 - modified	Corrected Mean Wear Scar Diameter	685	µm

Sample Received Condition : Good (No Seal)
Seal Number : Not Applicable
Sampling Method : Not Applicable
Remarks : Method IP 450 was modified as the sample type was outside the scope of the test method and the test temperature was 25C. Therefore results should be considered indicative only.

The analysis results denoted by (j) are part of the laboratory NATA accreditation. Accredited for compliance with ISO/IEC 17025.

This report has been reviewed for accuracy, completeness, and comparison against specifications when available. The reported results are only representative of the samples submitted for testing. This report shall not be reproduced except in full, without approval of the laboratory. All work is performed in accordance with Intertek Standard Terms and Conditions of Service which is available on request and at http://www.intertek.com/terms.

Signed: ____________ Date: 01-Mar-2016
Joshua Camens, Supervisor

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Australian Government
Department of the Environment and Energy

Diesel fuel quality standard

Management of Diesel Oil Burn Systems

The use of oil burn systems in diesel vehicles can potentially breach section 20 of the *Fuel Quality Standards Act 2000* if the addition of oil to the diesel within the engine results in the diesel not complying with the Fuel Standard (Automotive Diesel) Determination 2001.

As the Australian Government is committed to international best practice regulation of fuel quality, it has been decided not to amend the determination to allow the use of oil burn systems in any diesel vehicles operating in Australia.

It is considered that there is enough concern about the potential impacts on sulfur levels in diesel from the addition of used motor oil to warrant this decision.

Management of Diesel Oil Burn Systems - position paper

Environmental standards

The first suite of national fuel standards, which came into force on 1 January 2002, regulates petrol and diesel parameters that have a direct impact on the environment ('environmental standards').
The standards will have a major impact on the amount of toxic pollutants in vehicle emissions, such as benzene and particles, with studies estimating reductions of up to 50 per cent for some pollutants over 20 years. This is great news for our health, with cleaner air helping to reduce the number of serious respiratory illnesses and asthma cases, particularly in children.

Operability standards

A second suite of national fuel standards came into force on 16 October 2002. These standards ('operability standards') address those parameters of diesel that do not have a direct impact on emissions but, if not controlled, can have adverse impacts on the efficient operation of the engine.

Further operability standards are being developed that may include:

- for diesel - the parameters are appearance, acidity, cloud point and cold filter plugging point.

Summary table

The environmental and operability standards are consolidated in the following tables. The legal instrument implementing the standard is:

Fuel Standard (Automotive Diesel) Determination 2001

Diesel standards

Parameter	National standard	Date of effect	Test Method
Biodiesel [1]	5.0% volume by volume (max)	1-Mar-09	EN 14078
Sulfur	500 ppm (max)	31-Dec-02	ASTM D5453
	50 ppm (max)	1-Jan-06	
	10 ppm (max)	1-Jan-09	
Cetane Index	46 (min) index	1-Jan-02	ASTM D4737
Derived Cetane Number (of diesel containing biodiesel)	51.0 (min)	21-Feb-09	ASTM D6890
Density	820 (min) to 860 (max) kg/m^3	1-Jan-02	ASTM D1298
	820 (min) to 850 (max) kg/m^3	1-Jan-06	
Distillation T95	370°C (max)	1-Jan-02	ASTM D86
	360°C (max)	1-Jan-06	
Polyaromatic hydrocarbons (PAHs)	11% m/m (max)	1-Jan-06	IP391
Ash	100 ppm (max)	1-Jan-02	ASTM D482
Viscosity	2.0 to 4.5 cSt @ 40°C	1-Jan-02	ASTM D445
Carbon Residue (10% distillation residue)	0.2 mass % max	16-Oct-02	ASTM D4530
Water and sediment	0.05 vol % max	16-Oct-02	ASTM D2709
Water (all diesel containing biodiesel)	200 mg/kg (max)	21-Feb-09	ASTM 6304
Conductivity @ ambient temp	50 pS/m (Min) @ambient temp (all diesel held by a terminal or refinery for sale or distribution)	16-Oct-02	ASTM D2624
Oxidation Stability	25 mg/L max	16-Oct-02	ASTM D2274
Colour	2 max	16-Oct-02	ASTM D1500
Copper Corrosion (3 hrs @ 50°C)	Class 1 max	16-Oct-02	ASTM D130

Attachment 2

Flash point	61.5°C min	16-Oct-02	ASTM D93
Filter blocking tendency	2.0 max	16-Oct-02	IP 387
Lubricity	0.460 mm (max) (all diesel containing less than 500 ppm sulfur)	16-Oct-02	IP 450

[1] The biodiesel component of diesel must meet the requirements of fuel quality standard for biodiesel set out in the Fuel Standard (Biodiesel) Determination 2003.

Disclaimer

The information contained on this page is of a general nature only and should be read in conjunction with the *Fuel Quality Standards Act 2000*, Fuel Quality Standards Regulations 2001 and the Fuel Standard (Automotive Diesel) Determination 2001. Fuel suppliers may wish to seek legal advice about their obligations under this legislation.

Revision A

Marine Fuel Oil (MGO & HFO) and FCC Additive Technical Analysis

ADDF-REP-TA-0006

Michelle Lam

MARINE FUEL OIL (MGO & HFO) AND FCC ADDITIVE TECHNICAL ANALYSIS

ADDF-REP-TA-0006

Revision Number: A
Revision Date: 9/04/2017

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1 EXECUTIVE SUMMARY

Fuel Conditioner Concentrate (FCC) is added directly to fuel storage tanks to eliminate the problems associated with water contamination. FCC ensures that vehicle fuel systems remain clean and free from corrosion, gums, and varnishes. The main benefit of the FCC is derived from its regular use to maintain fuel systems free from liquid water. This prevents biological activity, reduces corrosion and inhibits reaction of the fuel with water. Regular use of FCC ensures that carburetors and fuel injectors work at peak performance eliminating poor running problems and expensive maintenance. The benefits of FCC extend throughout the fuel system.

Key summary based on the technical analysis of the MGO and HFO spiked with FCC improves and enhances the fuel properties in categories below:

Safety

- FCC does not impact the hazard level classification of the fuel which determines and affects the storage and handling fuel. With a low moderate hazard level fuel, the classification and hazard level remains unchanged with addition of FCC (minimal change in Flash Point).

Environmental

- FCC reduces white smoke on startup, and reduce NOx (Nitrogen Oxide) and Particulate Matter (PM) emissions (Increase in Cetane Index).
- FCC reduces Sulfur content in MGO DMB by 2.7% which is an important aspect with stricter sulfur in fuel requirement particularly in SECAs (Sulfur Emission Controlled Areas).

Combustion, Fuel Efficiency

- FCC helps to improve fuel combustion (Increase in Cetane Index) for MGO DMB with a minimal 0.4% increase.
- FCC does not modify composition (Gross Heat of Combustion / Calorific Value, Density, Distillation and Aromatics content) of the fuel which may cause incombustible components.

Performance, Maintenance

- FCC improves lubricity by a significant 16.8% in MGO and 3.2% in MGO DMB, which improves durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.
- FCC maintains this important characteristic of the fuel for Filter Blocking Tendency (FBT) for MGO which affects performance and lifetime of the engine.
- FCC maintains the non-corrosive nature of the fluid (copper corrosion test) where corrositivity of the fuel remain constant.

2 INTRODUCTION

FCC is an innovative and scientifically proven blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's engines. It's a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency. It is suitable for use for a large variety of fuel types.

With FCC, improvements in fuel efficiency and savings in maintenance costs are achieved through cleanliness and a better burn; as opposed to tampering with the combustion characteristics of the fuel.

2.1 BACKGROUND

FCC is a blend of blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's high performance engines. The Primary benefits of FCC are:

- Solubilises liquid water into the fuel.
- Reduces or eliminates the conditions favourable to the growth of microorganisms.
- Stabilises fuel by inhibiting the formation of gums and varnish.
- Inhibits corrosion of fuel system components.
- Promotes a uniform fuel spray pattern in combustion chambers, thus reducing carbonisation and improving combustion efficiency.
- Inhibits formation of corrosive acids in combustion chambers.

2.2 DOCUMENT SCOPE

The intent of this document scope is to provide technical analysis on 2 main types of Marine fuel oil with variation from both main categories;

- Marine Gas Oil (MGO),
- Marine Gas Oil type DMB,
- Heavy Fuel Oil (HFO) @ 180 cSt and
- Heavy Fuel Oil (HFO) @ 380 cSt.

The properties of the marine fuel are assessed after addition of fuel additive, herein referred to as FCC (spiked with ratio of 1:4000) and analysis is made in comparison to control sample. The primary properties assessed (based on Report of Analysis – Attachment 1) are:

Properties	**MGO**	**MGO (DMB)**	**HFO** (180 cSt)	**HFO** (380 cSt)
• Flash Point,	✓	✓	✓	✓
• Filter Blocking Tendency,	✓	✗	✗	✗
• Mean Wear Scar Diameter / lubricity	✓	✓	✗	✗
• Gross Heat of Combustion / Calorific Value	✓	✓	✓	✓
• Cetane Index,	✓	✓	✗	✗
• Density,	✓	✓	✓	✓
• Distillation,	✓	✓	✗	✗
• Sulfur Content,	✓	✓	✓	✓
• Copper Corrosion	✓	✓	✗	✓
• Aromatics.	✓	✓	✗	✗

2.3 REQUIREMENTS / SPECIFICATIONS

2.3.1 SPECIFICATIONS FOR MGO

Marine gas oil (MGO) is a marine version of normal diesel and is used on the vessels to power the main engines and generator sets, to provide propulsion and general services to the vessels, such as power and heating. An international ISO standard ISO 8217 is setup to define the requirements for petroleum fuels for use in marine diesel engines and boilers prior to appropriate treatment before use (Ref [7]).

The requirements for MGO (Distillate Marine Fuel (with density < 900 kg/m³) are as summarised in Table 2.1 below:

Table 2.1: Requirements for MGO (Distillate Marine Fuel) (Ref [7])

Specification of properties	Category ISO-F-DMX/DMA/DMZ/DMB
Kinematic viscosity (cSt) (min / max)	1,400 / 6,000
Density (kg/m³) (max)	890 – 900
Cetane Index (min)	35 – 45
Sulfur (mass %) (max)	1.0* – 2.0
Flash Point (°C) (min)	43 – 60
Wear Scar Diameter (µm) (max)	520

*The Sulfur in fuel requirement is reduced from 1.0% to 0.1% as from 1 January 2015 in SECAs (Sulfur Emission Controlled Areas).

2.3.2 SPECIFICATIONS FOR HFO

HFO, also known as “residual fuel oil”, is based on the high viscosity, tar-like mass, which remains after the distillation and subsequent cracking of crude oil in order to produce lighter hydrocarbon products, such as petrol, distillate diesel fuels and heating oil or feedstocks for lubricants. RMA, RMB, RMD, RME, RMG or RMK are the international trade names.

The requirements for HFO as per ISO standard ISO 8217 (Ref. [6]) are as summarised in Table 2.2 below:

Table 2.2: Requirements for HFO (Heavy Fuel Oil) (Ref [6])

Specification of properties	Values
Kinematic viscosity (cSt) (min / max)	55 at 100ºC / 700 at 50ºC
Density (kg/m³) (max)	1,010 at 15ºC
Flash Point (°C) (min)	60
Hydrogen Sulfide (mg/kg) (max)	2.0
Pour Point (°C) (max)	30
Acid number (mg KOH/g) (max)	2.5
Total sediment aged (mass %) (max)	0.10

3 ABBREVIATIONS & DEFINITIONS

3.1 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ASTM	American Standard Test Method
CO	Carbon Monoxide
CN	Cetane Number
DMB	Distillate Marine fuel oil type B (No. 4 or No. 5 fuel oil)
FBT	Filter Blocking Tendency
FCC	Fuel Conditioner Concentrate
HFO	Heavy Fuel Oil
IEC	International Electrotechnical Commission
IP	International Protection
ISO	International Organization for Standardization
MGO	Marine Gas Oil
NATA	National Association of Testing Authorities, Australia
NOx	Nitrogen Oxide
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
SECA	Sulfur Emissions Controlled Areas

The classification for ISO 8217 standards provides detailed specifications / categories of marine fuels based on the main applications and characteristics of the products. The classification is broadly broken down into distillate fuels and residual fuels (Ref [11]).

The products are designated by a code that consists of:

<table>
<tr><th>Initials</th><th>Category</th><th>Type</th><th>Application</th><th>Properties</th></tr>
<tr><td rowspan="2">ISO</td><td>F</td><td>D / R</td><td>M</td><td>X, A, B, C, …, K</td></tr>
<tr><td>Petroleum Fuels</td><td>Distillate / Residue</td><td>Marine</td><td>-</td></tr>
<tr><td colspan="5">ISO-F-DMX / DMA / DMZ / DMB</td></tr>
<tr><th colspan="2">Distillate Fuel</th><th colspan="2">Kinematic viscosity (mm²/s at 50ºC)</th><th>Density (kg/m³ at 15ºC)</th></tr>
<tr><td colspan="2">DMX</td><td colspan="2">1.4 to 5.5</td><td>-</td></tr>
<tr><td colspan="2">DMA</td><td colspan="2">1.5 to 6.0</td><td>< 890</td></tr>
<tr><td colspan="2">DMB</td><td colspan="2">< 11</td><td>< 900</td></tr>
<tr><td colspan="2">DMC</td><td colspan="2">< 14</td><td>< 920</td></tr>
</table>

3.2 DEFINITIONS

The property's definitions are summarised as below:

Property	Definition
Flash Point	The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.
Filter Blocking Tendency	FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter.
Wear Scar Diameter	Measure of lubricity of fluid which is the ability of fluid or compound (in this case MGO) to act as a lubricant to minimize friction and damage to surfaces in contact under relative motion load.
Gross Heat of Combustion / Gross Calorific Value	Total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions. The chemical reaction is a hydrocarbon (MGO) reacting with oxygen to form carbon dioxide and water and releases heat. Directly impacts the economics of engine performance.
Cetane Index	Measures the performance / quality of a fuel in an engine by its ability for auto-ignition.
Density	Characteristics of a substance indicated as Mass per unit volume varies with temperature and pressure. This variation is typically small for solids and liquids but much greater for gases.
Distillation	Distillation (batch) provides boiling range of MGO. The distillation characteristics affects starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both. The presence of high boiling point components in fuels can significantly affect the degree of formation of solid combustion deposits.
Sulfur Content	Sulfur in MGO is converted to sulfur oxides during combustion which affects particulate emissions (forms sulfur dioxide (SO2) and sulfate (SO4) particulate matter (PM)), leads to engine cylinder wear and forms deposits in the engines.
Copper Strip Corrosion	Indicates potential for corrosive attack on metal parts / relative degree of corrosivity of MGO.
Aromatics	Group of hydrocarbons of which benzene is the parent. They are called "aromatics" because many of their derivatives have sweet or aromatic odors. Aromatics in hydrocarbons (MGO) increase particulate emissions and cause related problems in combustion.

3.3 REFERENCES

The references used in this document are:

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2. Dictionary of Chemical Engineering, Schaschke, Carl (ISBN 978-0-19-965145-0)
3. http://www.engineeringtoolbox.com/flash-point-fuels-d_937.html
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11. https://www.dieselnet.com/standards/inter/fuel_marine.php
12. https://en.wikipedia.org/wiki/Heat_of_combustion
13. http://ec.europa.eu/environment/air/transport/pdf/Report_Sulfur_Requirement.pdf
14. https://www.astm.org/Standards/D86.htm
15. Notes on Heavy Fuel Oil Publication, American Bureau of Shipping (ABS)

3.4 ATTACHMENTS

1. Intertek Report of Analysis
2. Everything You Need to Know About Marine Fuels, Chevron, Monique B. Vermeire – Section III Fuel Oil – Table 1 (Requirements for distillate marine fuels).
3. Heavy Fuel Oil Specifications

4 MARINE FUEL OIL PROPERTIES

4.1 FLASH POINT

4.1.1 DEFINITION

The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.

The rapid combustion occurs in the form of momentary flash point. Flash point data is important for the safe storage and transportation of volatile liquids. Flash Point for typical MGO and HFO are tabulated in Table 4.1 below:

Table 4.1: Flash Point for MGO / HFO Oils

Fuel	**Flash Point (°C)**
Standard MGO / Standard MGO DMB	70.00 / 68.00 (Att. 1)
Standard MGO + FCC / Standard MGO DMB + FCC	69.00 / 68.00 (Att. 1)
Standard HFO (180 cSt)	73.00 (Att. 1)
Standard HFO (180 cSt) + FCC	74.00 (Att. 1)
Standard HFO (380 cSt)	118.00 (Att. 1)
Standard HFO (380 cSt) + FCC	118.00 (Att. 1)
Biodiesel	130.00
Diesel Fuel (1-D)	37.78
Diesel Fuel (2-D)	52.22
Diesel Fuel (4-D)	54.44
Fuels Oil No.1	37.78 – 72.22
Fuels Oil No.2	52.22 – 95.56
Fuels Oil No.4	61.11 – 115.56
Fuels Oil No.5 Lite	68.89 – 168.89
Fuels Oil No.5 Heavy	71.11 – 121.11

4.1.2 ANALYSIS

A low flash point is a high fire hazard. The accepted, safe, minimum flash point for fuel oils established by most regulatory bodies is 60°C for Marine Gas Oils (Ref. 15) and 61.5°C based on ASTM D93 (Ref. 4) for safe storage and handling of fuel.

Standard MGO Flash Point is 70°C (Fuel Oil No. 4 – 5) and with addition of FCC, the Flash Point remain almost the same at 69°C and within the moderate low hazard level classification. MGO DMB flash point remained unchanged after addition of FCC at 68ºC.

Standard HFO (180 cSt) Flash Point is 73°C (Fuel Oil No. 4 – 5) and with addition of FCC, the Flash Point remain almost the same at 74°C. HFO (380 cSt) flash point remained unchanged after addition of FCC at 118ºC.

Hence, addition of FCC does not impact on Flash Point of the marine fuel and the storage and handling of the fluid.

Flash Point Hazard Level classification is summarised in Table 4.2 below:

Table 4.2: Hazard Level Classification based on Flash Point

Hazard Level	Flash Point (°C)
Very low hazard	> 93
Moderate low hazard	66 to 93
High to Moderate Hazard	38 to 66
Extremely High to High Hazard	-18 to 38
Extreme Hazard	< -18

4.2 FILTER BLOCKING TENDENCY

4.2.1 DEFINITION

FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter. Unstable fuels can form soluble gums or insoluble organic particulates. Both gums and particulates may contribute to injector deposits, and particulates can clog fuel filters. The formation of gums and particulates may occur gradually during long-term storage or quickly during fuel system recirculation caused by fuel heating. Sometimes a combination of fuel behaviour and fuel system design can cause filter plugging.

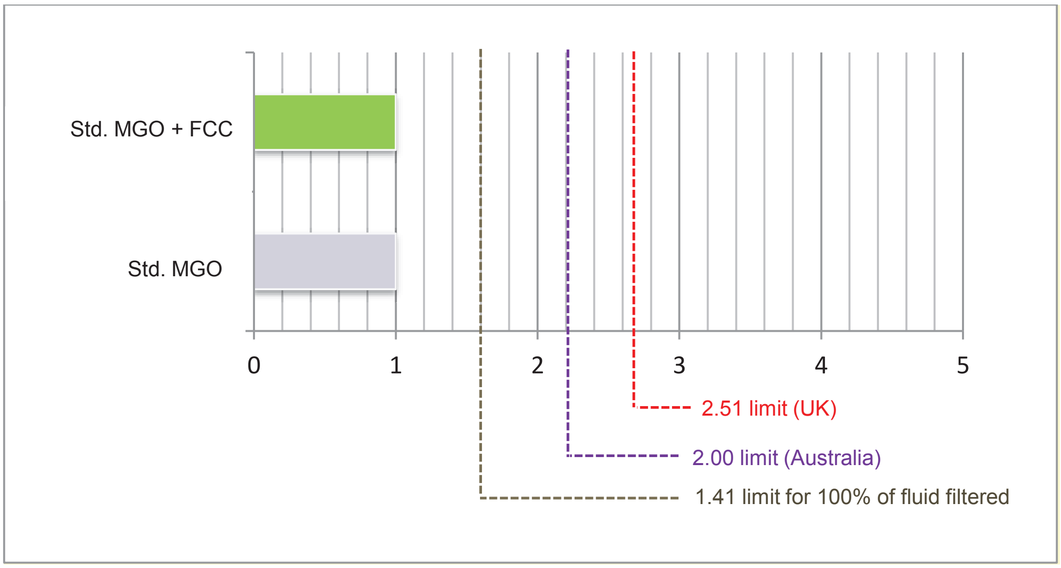
4.2.2 ANALYSIS

Based on the test results, there is no change in FBT after addition of FCC as the Standard MGO used as control sample has a low FBT. This low FBT of Standard MGO (control sample) and Standard MGO + FCC is 1.00, which is below 1.41, which means all of the volume 100% of flow could be filtered. This indicates that FCC maintains this important characteristic of the fuel for FBT which affects performance and lifetime of the engine.

The FBT limits are detailed below and illustrated in Figure 4.1:

- FBT values exceeded 1.41 indicates that not all of the volume could be filtered.
- Australia FBT limit value of 2.0 for Diesel fuels (Ref. 4).
- United Kingdom FBT limit < 2.51 (UK EN590 Specifications).

Figure 4.1: FBT (Fuel Specifications)



4.3 WEAR SCAR DIAMETER (LUBRICITY)

4.3.1 DEFINITION

Wear Scar Diameter is a measure of lubricity of fluid which is the ability of fluid or compound (in this case MGO) to act as a lubricant to minimize friction and damage to surfaces in contact under relative motion load.

Some moving parts of petrol fuel pumps and injectors are protected from wear by the fuel. Lubricity is ability of a lubricant (MGO) to minimize friction between and damage to surfaces in relative motion under load. The lubrication mechanism is a combination of hydrodynamic lubrication and boundary lubrication. In hydrodynamic lubrication, a layer of liquid prevents contact between the opposing surfaces. Fuels with higher viscosities will provide better hydrodynamic lubrication. Boundary lubrication becomes important when high load and/or low speed have squeezed out much of the liquid that provides hydrodynamic lubrication, leaving small areas of the opposing surfaces in contact. Boundary lubricants are compounds that form a protective anti-wear layer by adhering to the solid surfaces.

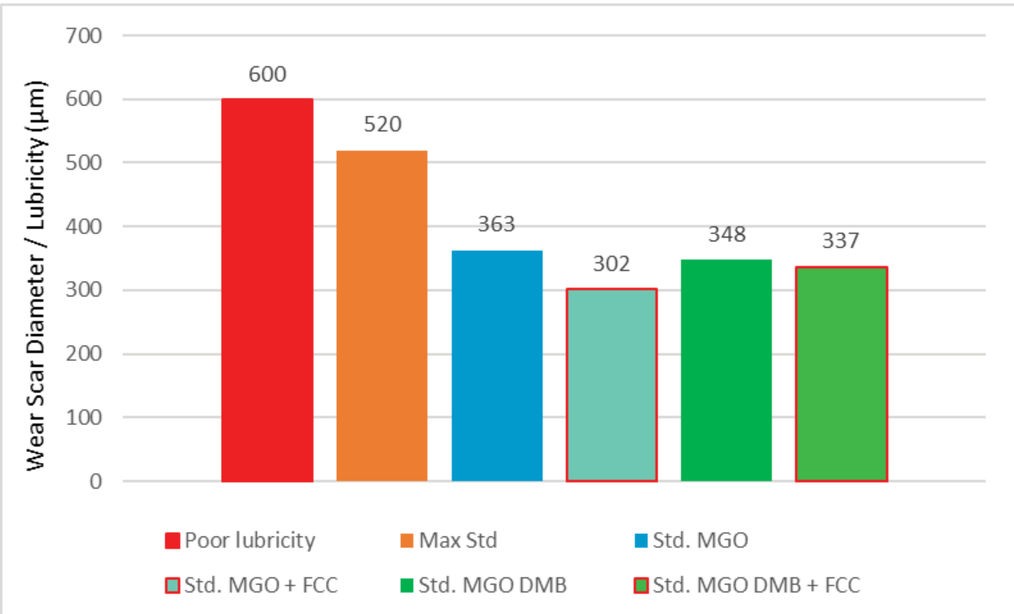
4.3.2 ANALYSIS

The maximum standard lubricity / wear scar diameter is 520 µm (Ref. 9) to ensure sufficient lubricity for the engine's operation. Poor lubricity / great scar diameter (>600 µm) could potentially causes excessive wear and at the extreme, causes catastrophic failure.

The lubricity of MGO improves by a significant 16.8% with addition of FCC from 363 µm to 302 µm and the lubricity of MGO DMB improves by 3.2% with addition of FCC from 348 µm to 337 µm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.

The specification of lubricity as illustrated in Figure 4.2 below.

Figure 4.2: Lubricity (MGO Specifications)



4.4 GROSS HEAT OF COMBUSTION / GROSS CALORIFIC VALUE

4.4.1 DEFINITION

The gross heat of combustion / gross calorific value is a measure of the total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions. The chemical reaction is a hydrocarbon (MGO/HFO) reacting with oxygen to form carbon dioxide and water and releases heat. This directly impacts the economics of engine performance.

4.4.2 ANALYSIS

Based on the laboratory analysis by Intertek (Attachment 1), MGO and HFO with addition of FCC has no/minimal impact on the gross heat of combustion / gross calorific value of the fuel. This indicates that FCC does not modify composition of the fuel which may cause incombustible components.

The aromatics content from the test results are as summarised below.

Properties	**MGO**	**MGO (DMB)**	**HFO** (180 cSt)	**HFO** (380 cSt)
Gross Heat of Combustion (Btu/lb)	19,661			18,252
Gross Heat of Combustion (Btu/lb) with FCC	19,661			18,247
Gross Calorific Value (MJ/kg)		45.61	42.29	
Gross Calorific Value (MJ/kg) with FCC		45.61	42.30	

4.5 CETANE INDEX

4.5.1 DEFINITION

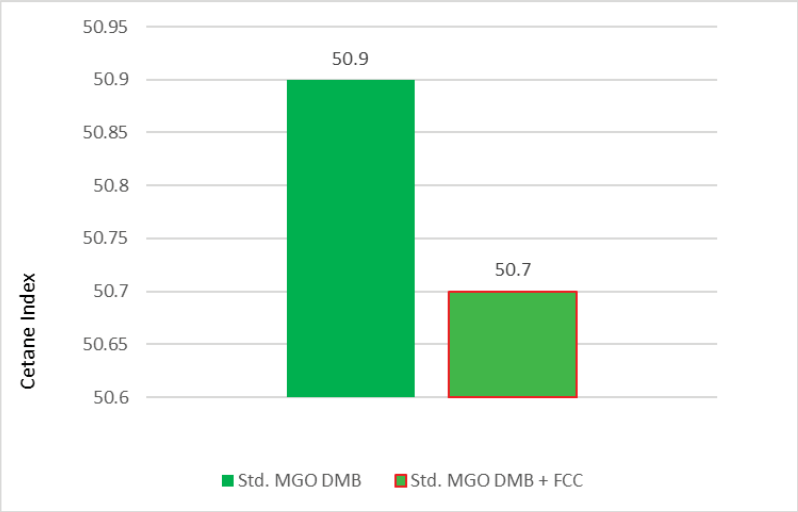
The quality of diesel fuels can be expressed as cetane number or cetane index. The cetane number (CN) is expressed in terms of the volume % of cetane (($C_{16}H_{34}$) which has high ignition (CN = 100)) in a mixture with alpha-methyl-naphthalene (($C_{11}H_{10}$) which has low ignition quality (CN = 0)) that has the same ignition characteristics as a fuel being tested in a standard engine. It is therefore, an indication of ease of self or auto-ignition characteristic of a fuel. The cetane index (CI) is a number calculated from the average boiling point and density of a petroleum fraction in the diesel fuel boiling range, which then estimates the CN of the fraction.

4.5.2 ANALYSIS

Based on the laboratory analysis by Intertek (Attachment 1), MGO with addition of FCC remained unchanged at 52.4. Based on the results for MGO DMB addition of FCC has improved the CI by a marginal 0.4% from 50.9 to 50.7. The slight increase of CI on the fuel increase the ease of self-ignition of the fuel and therefore enables engine to operate more effectively and improves engine performance. The specification of CI range is typically from 35 to 45.

The CI from the test results are as illustrated in Figure 4.3 below.

Figure 4.3: Cetane Index (MGO)



Increasing the cetane number improves fuel combustion, reduces white smoke on start-up, and tends to reduce NOx and PM emissions. NOx seems to be reduced in all engines, while PM reductions are engine-dependent. For high speed engine, high CI fuels are desirable as engine performance improvement on the high-speed engine is evident in comparison using low CI fuels.

4.6 DENSITY

4.6.1 DEFINITION

Characteristics of a substance indicated as mass per unit volume varies with temperature and pressure. This variation is typically small for solids and liquids (non-compressible) but much greater for gases (compressible). Non-compressible liquids / solids have relatively higher density than gas.

4.6.2 ANALYSIS

Changes in fuel density affect the energy content of the fuel brought into the engine at a given injector setting. Reducing fuel density tends to decrease NOx emissions in older technology engines that cannot compensate for this change. Emissions from modern engines, with electronic injection and computer control, are not influenced by the density of the fuel.

The density of MGO specification is typically 890 to 900 kg/m³ (Ref. 7). Standard Density of MGO (control sample) is 838.7 kg/m³, MGO DMB is 844.8 kg/m³, HFO (180 cSt) is 989.4 kg/m³ and HFO (380 cSt) is 988.4 kg/m³. Addition of FCC, have no impact on density for all marine fuel oil tested.

4.7 DISTILLATION

4.7.1 DEFINITION

The basic test method of determining the boiling range of a petroleum product by performing a simple batch distillation. The distillation (volatility) characteristics of hydrocarbons have an important effect on their safety and performance, especially in the case of fuels and solvents. The boiling range gives information on the composition, the properties, and the behaviour of the fuel during storage and use. Volatility is the major determinant of the tendency of a hydrocarbon mixture to produce potentially explosive vapours.

The distillation characteristics are critically important for both automotive and aviation gasolines, affecting starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both. The presence of high boiling point components in these and other fuels can significantly affect the degree of formation of solid combustion deposits.

HFO is residual fuel oil which remains after the distillation. The main components in HFO are alkanes, cycloalkanes and different carbon hydrides. The boiling range is between 300°C and ~700°C and are fuels which has less than 65% by volume (including losses) distils at 250°C by the ASTM D86 method. If the distillation cannot be determined by the ASTM D86 method, the petroleum product is likewise categorised as a heavy fuel oil.

4.7.2 ANALYSIS

The initial boiling point temperature and final boiling point temperature of MGO and MGO DMB is assessed and addition of FCC have minimal impact of the boiling point of the MGO. Addition of FCC into MGO changes the initial boiling point to 171.4ºC from 173.5ºC and the final boiling point to 360.5ºC from 360.6ºC. Similarly, for MGO DMB, addition of FCC changes the initial boiling point from 180.1ºC to 180.7ºC and the final boiling point from 360.3ºC to 361.5ºC.

Changes of boiling points have no impact on MGO performance as boiling points are used for categorisation of types of fuels.

4.8 SULFUR CONTENT

4.8.1 DEFINITION

Crude petroleum contains sulfur compounds, most of which are removed during refining. However, of the sulfur compounds remaining in the petroleum product, some can have a corroding action on various metals and this corrosivity is not necessarily related directly to the total sulfur content. The effect can vary according to the chemical types of sulfur compounds present. However, presence of sulfur in the MGO/HFO will results in emission of SOx (Sulfur oxides): Sulfur oxide refers to many types of Sulfur and oxygen containing compounds that can be found in ship exhaust gas. The most frequent Sulfur content in ships emissions in Sulfur dioxide (SO_2).

Sulfur in MGO/HFO is converted to sulfur oxides during combustion which affects particulate emissions (forms sulfur dioxide (SO_2) and sulfate (SO_4) particulate matter (PM)), leads to engine cylinder wear and forms deposits in the engines. The Sulfur in fuel requirement is reduced from 1.0% to 0.1% as from 1 January 2015 in SECAs (Sulfur Emission Controlled Area).

4.8.2 ANALYSIS

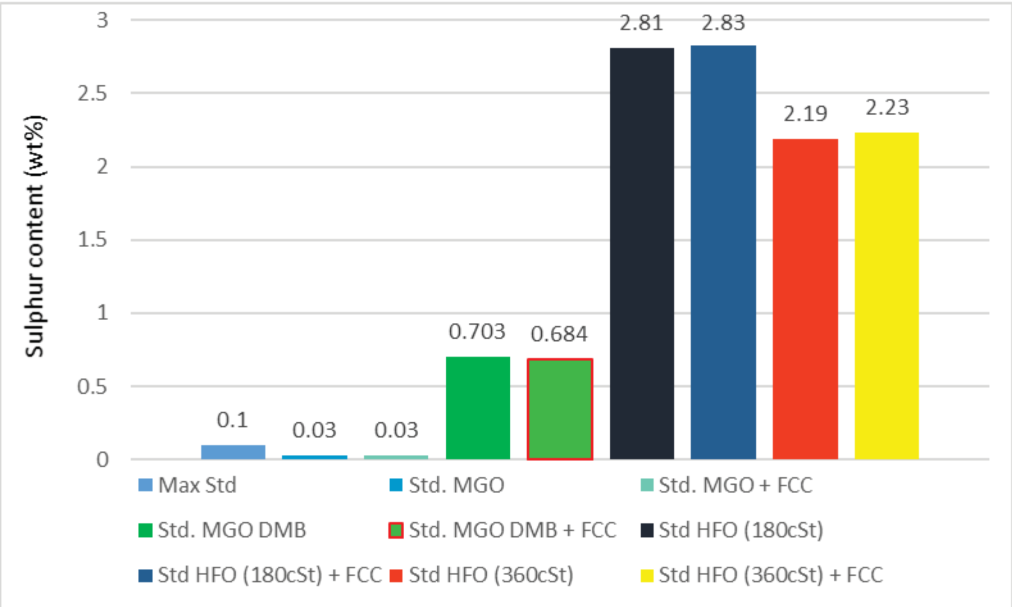
From the Intertek analysis (Attachment 1), MGO DMB Sulfur content has improved 2.70% with addition of FCC from 0.703 wt% down to 0.684 wt%. The improvement i.e. reduction in Sulfur content upon addition of FCC in MGO DMB will reduce the emission of Sulfur dioxide (SO_2).

No change is observed for MGO where the initial content of Sulfur in control sample is very low i.e. 0.030 wt%, much lower than the required Sulfur content of 0.1%.

Addition of FCC on HFO has a minimal increase in the Sulfur content from 2.81% to 2.83% for HFO (180 cSt) and from 2.19% to 2.23% for HFO (380 cSt).

The Sulfur content from the test results are as illustrated in Figure 4.3 below.

Figure 4.4: Sulfur Content (MGO/HFO)



4.9 COPPER CORROSION

4.9.1 DEFINITION

Crude petroleum contains sulfur compounds, most of which are removed during refining. However, of the sulfur compounds remaining in the petroleum product, some can have a corroding action on various metals and this corrosivity is not necessarily related directly to the total sulfur content. The effect can vary according to the chemical types of sulfur compounds present. The copper strip corrosion test is designed to assess the relative degree of corrosivity of a petroleum product (Ref. [10]).

4.9.2 ANALYSIS

The Copper Corrosion Test classification is provided in Table 4.3 below:

Table 4.3: Copper Corrosion Test

Class	Designation	Description
1	Slight Tarnish	**1a** Light orange, almost the same as a freshly polished strip **1b** Dark Orange
2	Moderate Tarnish	**2a** Claret Red **2b** Lavander **2c** Multi- colored with lavender blue and/or silver overlaid on claret red **2d** Silvery **2e** Brassy or gold
3	Dark Tarnish	**3a** Magenta overcast on brassy strip **3b** Multicolored with red and green showing (peacock), but no gray
4	Corrosion	**4a** Transparent black, dark gray or brown with peacock green barely showing **4b** Graphite or lusterless black **4c** Glassy or jet black

From the test results (as summarised below), addition of FCC will not change the corrositivity of the initial MGO / HFO which is desirable and indicates that FCC preserves the non-corrosive nature of the marine fuel.

Properties	**MGO**	**MGO (DMB)**	**HFO** (380 cSt)
Control sample Copper Corrosion Class	1b	1a	1b
Control sample + FCC Copper Corrosion Class	1b	1a	1b

4.10 AROMATICS

4.10.1 DEFINITION

Marine fuel oil contains approximately 60% aromatics, and is a high-density fraction. Aromatic hydrocarbons ($C_NH_{(2N-6)}$) possess a much higher specific gravity than the other classes. Aromatics are very stable under heat and are chemically active to a moderate degree. The aromatic compounds contain a higher proportion of carbon than the other hydrocarbon types. Due to this characteristic, they have a tendency to smoke, which somewhat limits their use in diesel engines (Ref. 15).

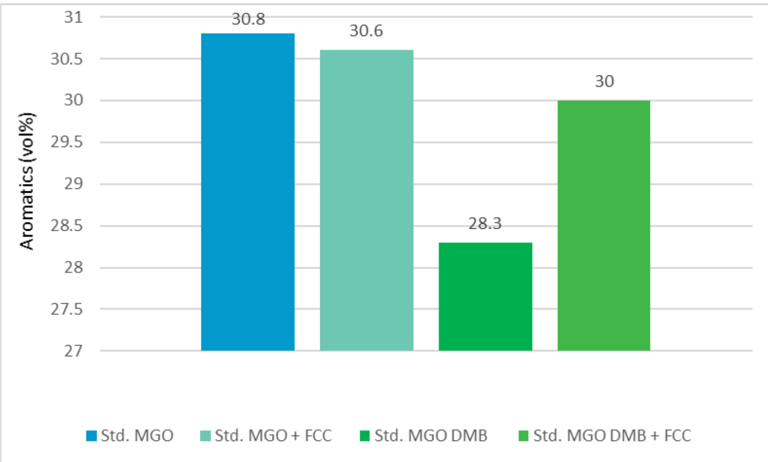
Most studies indicate that reducing total aromatics has no effect on the emissions of hydrocarbon and particulate matter. However, reducing total aromatics from 30% to 10% reduces NOx emissions (Ref. 9).

4.10.2 ANALYSIS

From the test results for MGO, the percentage of aromatics are slightly increased from 30.6 vol% to 30.8 vol% with addition of FCC. As for MGO DMB the percentage of aromatics are increased from 28.3 vol% to 30.0 vol% with addition of FCC. The change in aromatic content is illustrated in Figure 4.5 below.

As the percentage of change is below 10%, no significant impact is anticipated with addition of FCC on NOx emissions and fuel continues to remain stable under heat without significant change to fuel's composition that consequently affects combustion.

Figure 4.5: Aromatics (MGO)



5 SUMMARY

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Flash Point	The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.	ASTM D93	Indication of fire and explosion hazard which is important for the safe storage and transportation of volatile liquids. A low flash point is a high fire hazard.	• Very low hazard > 93°C • Moderate low hazard, 66 to 93°C • High to Moderate Hazard, 38 to 66°C • Extremely High to High Hazard, -18 to 38°C • Extreme Hazard < -18°C	70°C to 69°C (no impact)	68°C (no change).	73°C to 74°C (no impact).	118°C to 118°C (no change).
Filter Blocking Tendency	FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter.	IP 387 (Procedure A)	At low temperatures below the cloud point of diesel fuel, wax precipitates from fuel and can cause filter blocking and affecting quality of fuel.	If values exceeded 1.41 not all of the volume could be filtered. Limit < 2.51 (UK EN590 Specifications).	1.00 – No change / impact.	-	-	-

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Wear Scar Diameter / Lubricity	Ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load.	IP 450	Poor lubricity causes excessive wear and at the extreme, causes catastrophic failure.	>600 µm might not prevent excessive wear Specification of 520 µm max	302 µm (16.8% reduction / improvement from 363 µm)	337 µm (3.2% reduction / improvement from 348 µm)	-	-
Gross Heat of Combustion / Gross Calorific Value	Total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions.	ASTM D4838-00(10)	Directly impacts the economics of engine performance.	-	19,661 Btu/lb (no change)	45.61 MJ/kg (no change)	42.3 MJ/kg from 42.29 MJ/kg (no impact)	18,247 Btu/lb from 18,252 Btu/lb (minimal 0.03% decrease, no impact)
Cetane Index	Measures the performance / quality of a fuel in a diesel engine by its ability for auto-ignition.	ASTM D4737	Increase in Cetane will reduce emission of NOx [a]. High speed engine operates more effectively with high CI fuels.	• CI of 45 (Diesel No. 1) is used in high speed engines, trucks and buses. • CI of 40 (No. 2). • CN = 30 is used as Railroad diesel fuels (similar to the heavier automotive diesel fuels, but have higher boiling ranges up to 400°C.	52.4 (no change)	50.7 (0.4% increase from 50.9).	-	-

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Density	Characteristics of a substance indicated as Mass per unit volume varies with temperature and pressure.	ASTM 4052	Affects heating value and hence fuel economy. Density to be used in equation along with Heating Value to determine Heat of Combustion which consequently affects engine performance. Reduction in density will reduce NOx emissions [(a)].	MGO: Range from 890 – 900 kg/m³ depending on country / location. HFO: 1010 kg/m³	838.7 kg/m³ (no change)	844.9 kg/m³ from 844.8 kg/m³ (0.01% increase, no impact)	989.4 kg/m³ (no change)	988.3 kg/m³ from 988.4 kg/m³ (0.01% decrease, no impact)
Distillation	Distillation (batch) provides boiling range of MGO. The distillation characteristics affects starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both.	ASTM D86-15	The presence of high boiling point components in fuels can significantly affect the degree of formation of solid combustion deposits.	-	Initial boiling point to 171.4ºC from 173.5ºC, final boiling point to 360.5ºC from 360.6ºC – no impact	Initial boiling point from 180.1ºC to 180.7ºC, final boiling point from 360.3ºC to 361.5ºC – no impact	-	-

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Sulfur Content	Sulfur in MGO is converted to sulfur oxides during combustion which affects particulate emissions (forms sulfur dioxide (SO_2) and sulfate (SO_4) particulate matter (PM)),	ASTM D4294-16e1	Sulfur leads to engine cylinder wear and forms deposits in the engines.	0.5 – 2.0 wt%	0.0030 wt% (no change)	0.684 wt% (2.7% improvement from 0.703 wt%)	2.83 wt% (slight increase from 2.81 wt%)	2.23 wt% (slight increase from 2.19 wt%)
Copper Corrosion	Indicates potential for corrosive attack on metal parts / relative degree of corrosivity of marine fuel.	ASTM D130-12	Corrosion of metal parts of equipment / engine	1 – slightly tarnish 2 – moderate tarnish 3 – dark tarnish 4 – corrosion	1b (no change)	1a (no change)	-	1b (no change)
Aromatics	Group of hydrocarbons of which benzene is the parent. They are called "aromatics" because many of their derivatives have sweet or aromatic odors.	ASTM D1319-15	Aromatics in hydrocarbons (MGO/HFO) increase particulate emissions and cause related problems in combustion.	No specification for MGO/HFO. Limit applies to diesel < 11vol%	30.8 vol% from 30.6 vol% (increase 0.65%, no impact)	30 vol% from 28.3 vol% (increase 6%, no impact)	-	-

(a) For heavy duty engine emissions.

Key summary based on the technical analysis of the MGO and HFO spiked with FCC on a comparative basis to a MGO and HFO control sample respectively:

1. **Flash Point**: No change in classification of hazard level (moderate low hazard). Hence, addition of FCC does not impact on Flash Point of the MGO and HFO in storage and handling of the fluid / fuel.
2. No change in **FBT**. FCC maintains this important characteristic of the fuel for FBT which affects performance and lifetime of the engine.
3. **Wear Scar Diameter / Lubricity:** Improves by a significant 16.8% with addition of FCC in MGO from 363 μm to 302 μm and a 3.2% improvement with addition of FCC in MGO DMB from 348 μm to 337 μm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.
4. **Gross Heat of Combustion / Calorific Value**: Addition of FCC into MGO and HFO has no/minimal impact on the gross heat of combustion / gross calorific value of the fuel which indicates that FCC does not modify composition of the fuel which may cause incombustible components.
5. **Cetane Index:** Increasing the cetane number improves fuel combustion, reduces white smoke on startup, and tends to reduce NOx and PM emissions. MGO DMB Cetane Index is slightly increased with addition of FCC from 50.7 to 50.9.
6. No change in **Density**. MGO and HFO are high density fuel and addition of FCC have no change this property.
7. No change in **Distillation**: Similarly, as MGO and HFO are residue fuel in distillation process and stable under heat and characteristic of the fuel remain unchanged with addition of FCC.
8. **Sulfur Content**: Addition of FCC in MGO DMB yields an improvement of 2.7% reduction of Sulfur content from 0.703 wt% to 0.684 wt% which is an important aspect with stricter sulfur in fuel requirement particularly in SECAs (Sulfur Emission Controlled Areas).
9. **Copper Corrosion**: No further corrosion is observed with addition of FCC where the copper test readings remained constant before and after addition into MGO and HFO.
10. **Aromatics**: Minimal changes in aromatics content upon addition of FCC with slight 0.65% increase in aromatics for MGO from 30.6 vol% to 30.8 vol%. An increase of 6% is observed with addition of FCC into MGO DMB from 28.3 vol% to 30 vol%. Changes is minimal and fuel continues to remain stable under heat without significant change to fuel's composition that consequently affects combustion.

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Report of Analysis

Justin West
Addfuel
PO Box 318
Nedlands
WA,6909
Australia

Laboratory Report ID : 2678653
Job No. : 2017-PTAD-000105
Client Reference : Not Supplied

Sample ID	: 2017-PTAD-000105-002	**Date Taken**	: Not Supplied
Sample Designated as	: MGO	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: MGO (without Additive)		

Method		Test	Result	Units
ASTM D93		Procedure Used	A	
		Corrected Flash Point	70.0	°C
IP 387	i	Filter Blocking Tendency	1.00	
IP 450	i	Corrected Mean Wear Scar Diameter	363	µm
ASTM D4868		Gross Heat of Combustion	19661	BTU/lb
ASTM D976		Cetane Index	52.4	
ASTM D4052	i	Density @ 15°C	0.8387	kg/L
ASTM D86	i	Barometric Pressure	763	mm Hg
		Initial Boiling Point	173.5	°C
	i	5% Recovery	203.5	°C
	i	10% Recovery	215.4	°C
	i	20% Recovery	234.2	°C
	i	30% Recovery	249.3	°C
	i	40% Recovery	262.1	°C
	i	50% Recovery	273.7	°C
	i	60% Recovery	285.5	°C
	i	70% Recovery	298.1	°C
	i	80% Recovery	313.3	°C
	i	85% Recovery	322.3	°C
	i	90% Recovery	334.4	°C
	i	95% Recovery	352.1	°C
		Final Boiling Point	360.6	°C
	i	Corrected Loss	0.5	Vol %
	i	Corrected Residue	1.8	Vol %
	i	Corrected Total Recovery	99.5	Vol %
IP 336	i	Sulfur Content	< 0.030	% (m/m)
ASTM D130	i	Copper Corrosion @ 50°C (122°F)/3 hr	1b	
ASTM D1319	i	Aromatics	30.6	Vol %

Sample Received Condition	: Good (No Seal)
Seal Number	: None
Sampling Method	: Not Applicable
Remarks	: Not Supplied

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13658

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Report of Analysis

Laboratory Report ID : 2678653
Job No. : 2017-PTAD-000105
Client Reference : Not Supplied

Sample ID	: 2017-PTAD-000105-003	**Date Taken**	: Not Supplied
Sample Designated as	: MGO	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: MGO + FCC Fuel Conditioner by AddFuel (1:4000)		

Method		Test	Result	Units
ASTM D93		Procedure Used	A	
		Corrected Flash Point	69.0	°C
IP 387	i	Filter Blocking Tendency	1.00	
IP 450	i	Corrected Mean Wear Scar Diameter	302	µm
ASTM D4868		Gross Heat of Combustion	19661	BTU/lb
ASTM D976		Cetane Index	52.4	
ASTM D4052	i	Density @ 15°C	0.8387	kg/L
ASTM D86	i	Barometric Pressure	767	mm Hg
		Initial Boiling Point	171.4	°C
	i	5% Recovery	203.4	°C
	i	10% Recovery	214.8	°C
	i	20% Recovery	234.2	°C
	i	30% Recovery	249.1	°C
	i	40% Recovery	262.5	°C
	i	50% Recovery	273.5	°C
	i	60% Recovery	285.3	°C
	i	70% Recovery	298.0	°C
	i	80% Recovery	312.8	°C
	i	85% Recovery	321.8	°C
	i	90% Recovery	333.4	°C
	i	95% Recovery	350.5	°C
		Final Boiling Point	360.5	°C
	i	Corrected Loss	0.0	Vol %
	i	Corrected Residue	1.8	Vol %
	i	Corrected Total Recovery	100.0	Vol %
IP 336	i	Sulfur Content	< 0.030	% (m/m)
ASTM D130	i	Copper Corrosion @ 50°C (122°F)/3 hr	1b	
ASTM D1319	i	Aromatics	30.8	Vol %

Sample Received Condition : Good (No Seal)
Seal Number : None
Sampling Method : Not Applicable
Remarks : Not Supplied

Attachment 1 (B)

Sample ID	: 2017-PTAD-000105-004	**Date Taken**	: Not Supplied
Sample Designated as	: HFO 380cst	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: HFO 380cst (without Additive)		

Method	Test	Result	Units
ASTM D93	Procedure Used	B	
	Corrected Flash Point	118.0	°C

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Report of Analysis

Laboratory Report ID	: 2678653
Job No.	: 2017-PTAD-000105
Client Reference	: Not Supplied

Sample ID	: 2017-PTAD-000105-004	**Date Taken**	: Not Supplied
Sample Designated as	: HFO 380cst	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: HFO 380cst (without Additive)		

Method		Test	Result	Units
ASTM D4868		Gross Heat of Combustion	18252	BTU/lb
IP 365	j	Density @ 15 °C	0.9884	kg/L
ASTM D4294		Sample Preparation	Centrifuged	
		Sulfur Content	2.19	Wt %
ASTM D130	j	Copper Corrosion @ 50°C (122°F)/3 hr	1b	

Sample Received Condition	: Good (No Seal)
Seal Number	: None
Sampling Method	: Not Applicable
Remarks	: Not Supplied

Sample ID	: 2017-PTAD-000105-005	**Date Taken**	: Not Supplied
Sample Designated as	: HFO 380cst	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: HFO 380cst + FCC Fuel Conditioner by AddFuel (1:4000)		

Method		Test	Result	Units
ASTM D93		Procedure Used	B	
		Corrected Flash Point	118.0	°C
ASTM D4868		Gross Heat of Combustion	18247	BTU/lb
IP 365	j	Density @ 15 °C	0.9883	kg/L
ASTM D4294		Sample Preparation	Centrifuged	
		Sulfur Content	2.23	Wt %
ASTM D130	j	Copper Corrosion @ 50°C (122°F)/3 hr	1b	

Sample Received Condition	: Good (No Seal)
Seal Number	: None
Sampling Method	: Not Applicable
Remarks	: Not Supplied

The analysis results denoted by (j) are part of the laboratory NATA accreditation. Accredited for compliance with ISO/IEC 17025.

This Report supersedes Laboratory Report ID 2635282 issued on 21-Feb.2017.
Test IP450 result was amended.

Amended Report of Analysis

Signed: ______________________ Date: 06-Apr.2017

Michelle Fernandez, Laboratory Supervisor

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13658

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Attachment 1 (C)

CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-001

SAMPLE NO. : 2017-MIS-012165-001
JOB NO :
DATE RECEIVED : 27-Mar-2017
REPRESENTING : INTERTEK - PORT ADELAIDE
ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : DMB
Source : Without Additive

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	68.0
Lubricity	IP 450-00	microns	Report	348
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	45.61
Calculated Cetane Index	ASTM D4737-10(Proc A)		Report	50.9
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.8448
Distillation Range	ASTM D86-15			
Initial Boiling Point	ASTM D86-15	°C	Report	180.1
10% Recovered	ASTM D86-15	°C	Report	218.1
20% Recovered	ASTM D86-15	°C	Report	236.1
30% Recovered	ASTM D86-15	°C	Report	251.7
40% Recovered	ASTM D86-15	°C	Report	265.7
50% Recovered	ASTM D86-15	°C	Report	278.2
60% Recovered	ASTM D86-15	°C	Report	289.6
70% Recovered	ASTM D86-15	°C	Report	301.5
80% Recovered	ASTM D86-15	°C	Report	315.1
90% Recovered	ASTM D86-15	°C	Report	332.8
95% Recovered	ASTM D86-15	°C	Report	347.1
Final Boiling Point	ASTM D86-15	°C	Report	360.3
Residue	ASTM D86-15	Vol %	Report	1.8
Loss	ASTM D86-15	Vol %	Report	0.2
Sulphur	ASTM D4294-16e1	wt %	Report	0.0703
Copper Strip Corrosion @ 50 °C for 3 hrs	ASTM D130-12		Report	1a
Aromatics	ASTM D1319-15	Vol %	Report	28.3

REMARKS :

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-001

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-002

SAMPLE NO. : 2017-MIS-012165-002
JOB NO :
DATE RECEIVED : 27-Mar-2017
REPRESENTING : INTERTEK - PORT ADELAIDE
ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : DMB
Source : With Additive (2017-MIS-012164-001) at Ratio 1:4000

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	68.0
Lubricity	IP 450-00	microns	Report	337
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	45.61
Calculated Cetane Index	ASTM D4737-10(Proc A)		Report	50.7
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.8449
Distillation Range	ASTM D86-15			
Initial Boiling Point	ASTM D86-15	°C	Report	180.7
10% Recovered	ASTM D86-15	°C	Report	217.7
20% Recovered	ASTM D86-15	°C	Report	235.8
30% Recovered	ASTM D86-15	°C	Report	251.2
40% Recovered	ASTM D86-15	°C	Report	265.6
50% Recovered	ASTM D86-15	°C	Report	277.7
60% Recovered	ASTM D86-15	°C	Report	289.0
70% Recovered	ASTM D86-15	°C	Report	301.4
80% Recovered	ASTM D86-15	°C	Report	314.8
90% Recovered	ASTM D86-15	°C	Report	332.1
95% Recovered	ASTM D86-15	°C	Report	346.3
Final Boiling Point	ASTM D86-15	°C	Report	361.5
Residue	ASTM D86-15	Vol %	Report	1.2
Loss	ASTM D86-15	Vol %	Report	0.3
Sulphur	ASTM D4294-16e1	wt %	Report	0.0684
Copper Strip Corrosion @ 50 °C for 3 hrs	ASTM D130-12		Report	1a
Aromatics	ASTM D1319-15	Vol %	Report	30.0

REMARKS :

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012155-001

SAMPLE NO. : 2017-MIS-012155-001

JOB NO :

DATE RECEIVED : 27-Mar-2017

REPRESENTING : INTERTEK - PORT ADELAIDE

ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : HFO 180cst
Source : Without Additive

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	73.0
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	42.29
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.9894
Sulphur	ASTM D4294-16e1	wt %	Report	2.81

REMARKS :

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012155-002

SAMPLE NO. : 2017-MIS-012155-002
JOB NO :
DATE RECEIVED : 27-Mar-2017
REPRESENTING : INTERTEK - PORT ADELAIDE
ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : HFO 180cst
Source : With Additive (2017-MIS-012164-001) at Ratio 1:4000

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	74.0
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	42.30
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.9894
Sulphur	ASTM D4294-16e1	wt %	Report	2.83

REMARKS :

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Table 1: Requirements for distillate marine fuels

Characteristics		Unit	Limit	Category ISO-F-				Test method reference
				DMX	DMA	DMZ	DMB	
Kinematic viscosity at 40°C[a]		mm²/s	max.	5,500	6,000	6,000	11.00	ISO 3104
			min.	1,400	2,000	3,000	2,000	
Density at 15°C		kg/m³	max.	–	890.0	890.0	900.0	see 7.1 ISO 3675 or ISO 12185
Cetane index		–	min.	45	40	40	35	ISO 4264
Sulfur[b]		mass %	max.	1.00	1.50	1.50	2.00	see 7.2 ISO 8754 ISO 14596
Flash point		°C	min.	43.0	60.0	60.0	60.0	see 7.3 ISO 2719
Hydrogen sulfide[c]		mg/kg	max.	2.00	2.00	2.00	2.00	IP 570
Acid number		mg KOH/g	max.	0.5	0.5	0.5	0.5	ASTM D664
Total sediment by hot filtration		mass %	max.	–	–	–	0.10[e]	see 7.4 ISO 10307-1
Oxidation stability		g/m³	max.	25	25	25	25[f]	ISO 12205
Carbon residue: micro method on the 10% volume distillation residue		mass %	max.	0.30	0.30	0.30	–	ISO 10370
Carbon residue: micro method		mass %	max.	–	–	–	0.30	ISO 10370
Cloud point		°C	max.	-16	–	–	–	ISO 3015
Pour point (upper)[d]	winter quality	°C	max.	–[j]	-6	-6	0	ISO 3016
	summer quality	°C	max.	–[j]	0	0	6	ISO 3016
Appearance		–	–	Clear and Bright[k]			[e,f,g]	see 7.6
Water		volume %	max.	–	–	–	0.30[e]	ISO 3733
Ash		mass %	max.	0.010	0.010	0.010	0.010	ISO 6245
Lubricity, corrected wear scar diameter (wsd 1.4) at 60°C[h]		µm	max.	520	520	520	520[g]	ISO 12156-1

a 1 mm²/s = 1 cSt.

b Notwithstanding the limits given, the purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Annex C.

c Due to reasons stated in Annex D, the implementation date for compliance with the limit shall be 1 July 2012. Until such time, the specified value is given for guidance. For distillate fuels the precision data are currently being developed.

d Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

e If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required, see 7.4 and 7.6.

f If the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.

g If the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.

h This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).

j Modified per approved correction to ISO 8217:2010.

k If the sample is dyed and not transparent, then the water limit and test method as given in 7.6 shall apply.

Table 2: Requirements for marine residual fuels

Characteristics	Unit	Limit	Category ISO-F-											Test method reference
			RMA	RMB	RMD	RME	RMG				RMK			
			10[a]	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50°C[b]	mm^2/s	max.	10.00	30.00	80.00	180.0	180.0	380.0	500.0	700.0	380.0	500.0	700.0	ISO 3104
Density at 15°C	kg/m^3	max.	920.0	960.0	975.0	991.0	991.0				1010.0			see 7.1 ISO 3675 or ISO 12185
CCAI	–	max.	850	860	860	860	870				870			see 6.3 a)
Sulfur[c]	mass %	max.	Statutory requirements											see 7.2 ISO 8754 ISO 14596
Flash point	°C	min.	60.0	60.0	60.0	60.0	60.0				60.0			see 7.3 ISO 2719
Hydrogen sulfide[d]	mg/kg	max.	2.00	2.00	2.00	2.00	2.00				2.00			IP 570
Acid number[e]	mg KOH/g	max.	2.5	2.5	2.5	2.5	2.5				2.5			ASTM D664
Total sediment aged	mass %	max.	0.10	0.10	0.10	0.10	0.10				0.10			see 7.5 ISO 10307-2
Carbon residue: micro method	mass %	max.	2.50	10.00	14.00	15.00	18.00				20.00			ISO 10370
Pour point (upper)[f] winter quality	°C	max.	0	0	30	30	30				30			ISO 3016
Pour point (upper)[f] summer quality	°C	max.	6	6	30	30	30				30			ISO 3016
Water	volume %	max.	0.30	0.50	0.50	0.50	0.50				0.50			ISO 3733
Ash	mass %	max.	0.040	0.070	0.070	0.070	0.100				0.150			ISO 6245
Vanadium	mg/kg	max.	50	150	150	150	350				450			see 7.7 IP 501, IP 470 or ISO 14597
Sodium	mg/kg	max.	50	100	100	50	100				100			see 7.8 IP 501 IP 470
Aluminium plus silicon	mg/kg	max.	25	40	40	50	60				60			see 7.9 IP 501, IP 470 or ISO 10478
Used lubricating oils (ULO): calcium and zinc; or calcium and phosphorus	mg/kg	–	The fuel shall be free from ULO. A fuel shall be considered to contain ULO when either one of the following conditions is met: calcium > 30 and zinc > 15; or calcium > 30 and phosphorus > 15											see 7.10 IP 501 or IP 470 IP 500

a This category is based on a previously defined distillate DMC category that was described in ISO 8217:2005, Table 1. ISO 8217:2005 has been withdrawn.

b 1 mm^2/s = 1 cSt.

c The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See 0.3 and Annex C.

d Due to reasons stated in Annex D, the implementation date for compliance with the limit shall be 1 July 2012. Until such time, the specified value is given for guidance.

e See Annex H.

f Purchasers shall ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

Attachment 3

Power Plants

HFO

HFO, also known as "residual fuel oil", is based on the high viscosity, tar-like mass, which remains after the distillation and subsequent cracking of crude oil in order to produce lighter hydrocarbon products, such as petrol , distillate diesel fuels and heating oil or feedstocks for lubricants.

The main components are alkanes, cycloalkanes and different carbon hydrides. The boiling range is between 300°C and ~700°C.

Due to its semi-fluid consistence, HFO has to be preheated to make it combustible in engines.

RMA, RMB, RMD, RME, RMG or RMK are the international trade names.

Cheap, but challenging

As a residual product, HFO is a relatively inexpensive fuel – it typically costs 30% less than distillate fuels (MDO/MGO) (Verlinkung). It thus became the standard fuel for large marine diesel engines during the oil crisis in the 1970s and 1980s, and it required extensive adaptation of the injection system and other components of low and medium speed engines – which are still the only reciprocating engines capable of running on HFO.

Most of our MAN medium speed liquid fuel engines (http://powerplants-staging.md-man.biz/products/liquid-fuel-engines/at-a-glance) can burn heavy fuel oil (HFO). Of course, our medium speed dual fuel engines (http://powerplants-staging.md-man.biz/products/dual-fuel-engines/at-a-glance) are capable of burning HFO in liquid fuel mode as well.

Fuel oil specification

Heavy fuel oil

ISO 8217, ISO-F-RM			**K700**
Fuel-system related characteristics values			
Viscosity (at 50 °C)	mm^2/s (cSt)	max.	700
Viscosity (at 100 °C)	mm^2/s (cSt)	max.	55
Density (at 15 °C)	kg/m^3	max.	1,010
Flash point	°C	min.	60
Pour point	°C	max.	30
Hydrogen sulfide	mg/kg	max.	2
Acid number	mg KOH/g	max.	2.5
Total sediment aged	mass %	max.	0.10
Engine-related characteristic values			
Carbon residues (Conradson)	m%	max.	20
Sulphur	m%	max.	5

Attachment 3

Ash	m%	max.	0.15
Vanadium	mg/kg (=ppm)	max.	450
Water	Vol.%	max.	0.5
Additional parameters			
Aluminium and silicon	mg/kg	max.	60
Asphalts	m%	max.	2/3 of carbon residues (Conradson)
Sodium	mg/kg		Sodium < 1/3 vanadium, sodium < 100
Used lubricating oil (ULO)	mg/kg		Ca >30 and Zn >15 or CA >30 and P >15

INDEX

6. THIRD PARTY VEHICLE EMISSIONS REPORTS

Revision A

Emissions Report – Mitsubishi Trition

ADDF-REP-TA-0003

Michelle Lam

EMISSIONS REPORT – MITSUBISHI TRITION

ADDF-REP-TA-0003

Revision Number: A
Revision Date: 24/01/2017

PREPARED BY

Name	Designation	Signature	Date
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1 EXECUTIVE SUMMARY

The major air pollutants are caused by emissions of exhaust from motor vehicles which are principal source that emits nitrogen oxides (NOx) and carbon monoxide (CO) in most capital cities worldwide. These ambient air pollutants, CO and NOx are part of the main concern pollutants as listed in the 1998 Ambient Air Quality National Environmental Protection Measure (Ambient Air Quality NEPM) and are both in top 3 ranks in the National Pollution Inventory Risk Ranking. The pollutants are of major concern as they pose different levels of risk to human health and adversely impacts the environment.

With regards to lowering and limiting these harmful vehicle emissions, Fuel Conditioner Concentrate (FCC), FCC is a non-hydrocarbon fuel conditioner that assists in achieving clean fuel, improves performance and increasing fuel efficiency, whilst most importantly lowering emissions of air pollutants.

Key summary based on the technical analysis of the emissions from Mitsubishi Triton Ute (Att. 1) with vehicle running on fuel without FCC additive (benchmark) and with addition of FCC:

CO emissions:

- Emissions of CO pollutant is ranked at No. 3 in the National Pollution Inventory Risk Ranking with a high health hazard factor (Ref. 7).
- A substantial 30% reduction of CO emissions at maximum rated power which reduces the CO concentration from 413 ppm to 252 ppm after addition of FCC.

NOx emissions:

- Emissions of NOx pollutant is ranked highest i.e. No. 1 in the National Pollution Inventory Risk Ranking with the highest environmental hazard factor (Ref. 7).
- A notable significant 79% reduction of NOx emissions at minimum rated power which reduces the NOx concentration from 130 ppm to 27 ppm after addition of FCC.
- At maximum rated power, a 10% reduction of NOx emissions is observed with NOx concentration reduced from 151 ppm to 136 ppm.

2 INTRODUCTION

The major air pollutants are caused by emissions of exhaust from motor vehicles which are principal source that emits nitrogen oxides and carbon monoxide in most capital cities worldwide. Traffic contributes more than 75% of carbon monoxide emissions and most emissions of nitrogen oxides (Ref. 7).

Statistics for Australia capital cities for year 2000–01 indicates that motor vehicles are estimated to have contributed 47% of nitrogen oxide levels in Perth and 82% in Southeast Queensland. Motor vehicles are estimated to be the source of more than 60% of carbon monoxide levels for all capital city airsheds other than Darwin (Ref. 7).

These air pollutants pose different levels of risk to human health and adversely impacts the environment. The ambient air pollutants of most concern in Australia are listed in the 1998 Ambient Air Quality National Environmental Protection Measure (Ambient Air Quality NEPM) which are carbon monoxide, nitrogen oxides, volatile organic compounds, lead, sulfur dioxide and particulate matter of less than 10 microns (PM10).

In environmental view of limiting harmful vehicle emissions, FCC is a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency.

2.1 BACKGROUND

FCC is a blend of blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today’s high performance engines. The Primary benefits of FCC are:

- Solubilises liquid water into the fuel.
- Reduces or eliminates the conditions favourable to the growth of microorganisms.
- Stabilises fuel by inhibiting the formation of gums and varnish.
- Inhibits corrosion of fuel system components.
- Promotes a uniform fuel spray pattern in combustion chambers, thus reducing carbonisation and improving combustion efficiency.
- Inhibits formation of corrosive acids in combustion chambers.

2.2 DOCUMENT SCOPE

This document scope provides technical analysis for comparison of emissions from vehicle type Mitsubishi Triton running on fuel before and after addition of fuel additive, herein referred to as FCC. Analysis is made on emissions of major pollutants as listed below:

- Carbon Monoxide and
- Nitrogen Dioxide.

2.3 AIR QUALITY STANDARD

The ambient air pollutants of most concern in Australia are listed in the 1998 Ambient Air Quality National Environmental Protection Measure (Ambient Air Quality NEPM) and the National Air Quality Standard is summarised in Table 2.1 (Att. 2):

Table 2.1: Australia National Air Quality Standard

Pollutant	Averaging Period	Maximum (ambient) concentration
Carbon monoxide	8 hours	9.0 ppm
Nitrogen dioxide	1 hour	0.12 ppm
	1 year	0.03 ppm
Photochemical oxidants (as ozone)	1 hour	0.10 ppm
	4 hours	0.08 ppm
Sulfur dioxide	1 hour	0.20 ppm
	1 day	0.08 ppm
	1 year	0.02 ppm
Lead	1 year	0.50 µg/m³
Particles as PM10	1 day	50 µg/m³

2.4 POLLUTANT INVENTORY RISK RANKING

The National Environment Protection Council Technical Advisory Panel (formed to recommend substances for inclusion in the National Pollutant Inventory to assessed the risks to human health and the environment from exposure to a substance listed in the inventory) risk assessments for the major air pollutants are summarised in Table 2.1.

Table 2.1 National Pollutant Inventory Risk Ranking (Selected Air Pollutants (Ref. 7))

Pollutant	*Health hazard*	*Environmental hazard*	*Combined rank*	*National Pollution Inventory rank*[1]
Nitrogen oxides—N_2O NO NO_2	1.5	3.0	4.5	1
Carbon monoxide—CO	2.0	0.8	2.8	3
Sulfur dioxide—SO_2	1.5	1.3	2.8	3
PM_{10}	1.2	1.3	2.5	7
Lead and compounds	1.7	1.5	3.2	11
Non-methane volatile organic compounds				
Xylene	1.3	1.0	2.3	9
Benzene	2.3	1.0	3.3	14
Toluene	1.3	1.3	2.6	33

Notes: The approach used to assess pollutants results in some substances receiving the same National Pollution Inventory rank. This ranking also considers human exposure to the pollutant. Excluded from the National Environment Protection Council list of approximately 400 substances were substances that had been banned or scheduled for phase-out, agriculture and veterinary chemicals, and those substances where other reporting was in place because of their ozone depleting or greenhouse effects.

Source: National Pollution Inventory Technical Advisory Panel (1999); National Pollution Inventory substance profiles (Environment Australia undated).

3 ABBREVIATIONS & DEFINITIONS

3.1 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ADR	Australia Design Rules (Control of Vehicle Emissions)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
FCC	Fuel Conditioner Concentrate
H_2O	Water
NOx	Nitrogen Oxide
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
PM	Particulate Matter
SO_2	Sulfur Dioxide
VOC	Volatile Organic Compound

3.2 POLLUTANT DESCRIPTION

The major pollutant assessed and its' adverse effects on human health and environment are described and summarised as below:

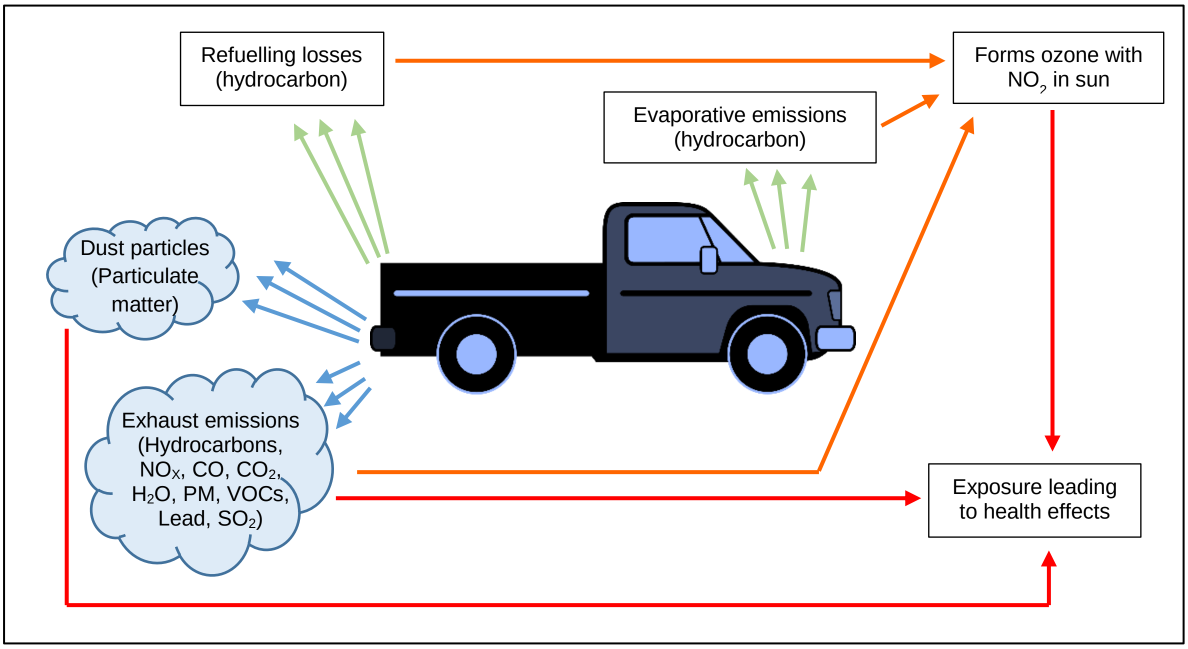
Pollutant		Description	Impact / Adverse Effects
CO	Carbon Monoxide	Carbon monoxide (CO) is generated from combustion process as a component of motor vehicle exhaust. This gaseous pollutant is produced when there is insufficient oxygen present in the combustion chamber which results in a partially oxidised fuel.	CO's toxicity stems from its ability to reduce the oxygen-carrying capacity of blood by preferentially bonding to haemoglobin and impacts human health.
NOx	Nitrogen Oxide	Nitrogen oxides (NOx), the term used to describe the sum of NO, nitrogen dioxide (NO_2), and other oxides of nitrogen. NOx is the sum of NO and NO_2 contents in exhaust gas (NOx = NO + NO_2).	While NO is non-toxic by itself, it contributes to ozone formation. "NO2 can irritate the lungs and lower resistance to respiratory infection…" (Ref. 6). Under some conditions, NOx is also an important precursor to particulate matter (Ref. 2), haze and acid rain.
NO	Nitric Oxide	NO makes up the largest content / contributor in exhaust gas (Ref. 4).	
NO_2	Nitrogen Dioxide	NO_2 in proportion 5-10% of NO (Ref. 4).	

3.3 VEHICLE EMISSIONS AND HEALTH EFFECTS

Pollutants are formed during the combustion process in the vehicle's engine. There is no direct relationship between regulated pollutants produced by the engine, tailpipe emissions of these pollutants, and vehicle mass or size.

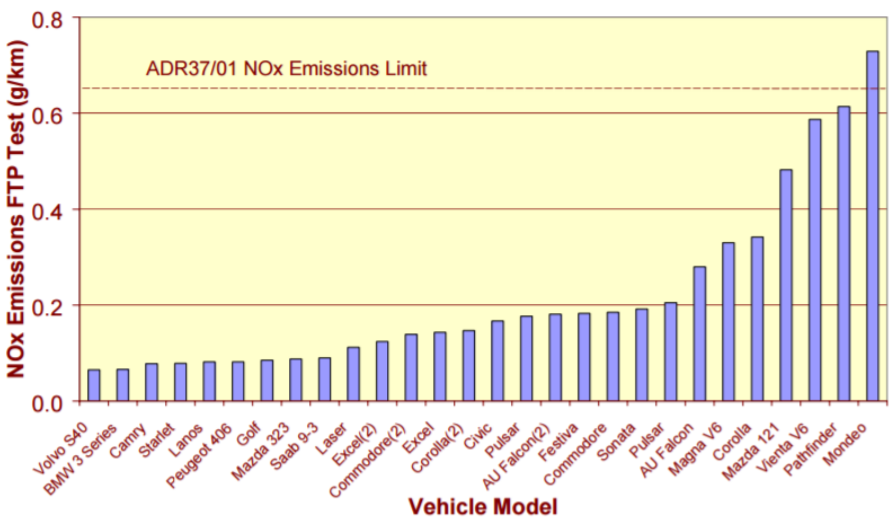
Non-combustion sources of ambient air pollution can include the evaporation of the fuel itself and vehicle movement can generate emissions of road dust and brake lining dust. The impact on human health from vehicle emissions are summarised in Figure 3.1:

Figure 3.1: Transport emissions and health effects



In Australia performance-based standards limit the amount of specific air pollutants that may be emitted by new vehicles. Each new vehicle model is required to comply with Australian Design Rules (Australian Design Rules are national standards under the Motor Vehicle Standards Act 1989) before it is supplied to the Australian market. Nitrogen Oxide emissions ADR37/01 Vehicles (Australia Design Rules compliance vehicles) are included in Figure 3.2 for emissions of CO for various vehicle make.

Figure 3.2: Nitrogen Oxide Emissions from ADR37/01 Vehicles on the ADR37/01 Test (Ref. 7)



Note Most vehicles in the Comparative Vehicle Emissions Study were designed to comply with ADR37/01.

Source Australian Government Department of Transport and Regional Services 2001

3.4 REFERENCES

The references used in this document are:

1. Certificate of Analysis Submission No: 58649 (PO: 3806), 25-Oct-2015 (Att. 1).
2. Diesel Fuel Technical Review, Chevron.
3. https://www.environment.gov.au/protection/air-quality/air-quality-standards
4. http://fluid.wme.pwr.wroc.pl/~spalanie/dydaktyka/combustion_en/NOx/NOx_formation.pdf
5. Clean Coal Engineering Technology, Miller, Bruce G., 2011
6. “Air Trends, September 2003 Report: National Air Quality and Emissions Trends Report, 2003 Special Studies Edition,” U.S. EPA, http://www.epa.gov/air/airtrends/aqtrnd03/
7. Health impacts of transport emissions in Australia: Economic costs, Australia Government, Department of Transport and Regional Services (https://bitre.gov.au/publications/2005/files/wp_063.pdf)

3.5 ATTACHMENTS

1. Intertek Geotech, Certificate of Exhaust Gas Analysis Serial No: MMAJYKL10GH013995 (before addition of FCC and after addition of FCC).
2. Australia Government Department of Environmental and Energy, Air Quality Standards in Australia.

4 EMISSIONS

The emissions from Mitsubishi Triton Ute (Attachment 1) with specifications as below are assessed with vehicle running on fuel without FCC additive (benchmark) and with addition of FCC. The Mitsubishi Triton's exhaust gas emission data is recorded at vehicle's minimum rated power (idle) and at maximum rated power (high idle).

Description	Data
Unit & Engine Make	Mitsubishi
Registration No.	1GCO 174
Model	Triton
Engine No.	MMAJYKL10GH013995
Engine Capacity	2400cc
Engine Power	133 kW
Total Hours / km Run	9,836 kms
Original Engine	Yes
Exhaust Treatment Type	Standard Turbo Diesel
Bank	Straight 4 Cylinder

4.1 CARBON MONOXIDE (CO)

4.1.1 DESCRIPTION

Carbon monoxide (CO) is generated from combustion process as a component of motor vehicle exhaust. This gaseous pollutant is produced when there is insufficient oxygen present in the combustion chamber which results in a partially oxidised fuel. High levels of carbon monoxide can be caused by a too rich fuel mixture, incorrect idle speed, faulty air cleaner or positive crankcase ventilation (PCV) valve, incorrect fuel pressure or faulty carburettor/injection system.

4.1.2 ANALYSIS

Based on the emissions test report (Att. 1), Mitsubishi Trition running at minimum rated power (idle) produces CO in the exhaust at a concentration of 7 ppm and increases slightly to 12 ppm with addition of FCC. This is a minimal 5 ppm increase and considering that the vehicle is idle, this concentration of emission is insignificant in comparison to emissions from vehicle running at normal load.

With vehicle running at maximum rated power, the CO concentration in exhaust gas emission is 413 ppm before addition of FCC and with addition of FCC, the CO emission is significantly reduced by 39% to 252 ppm.

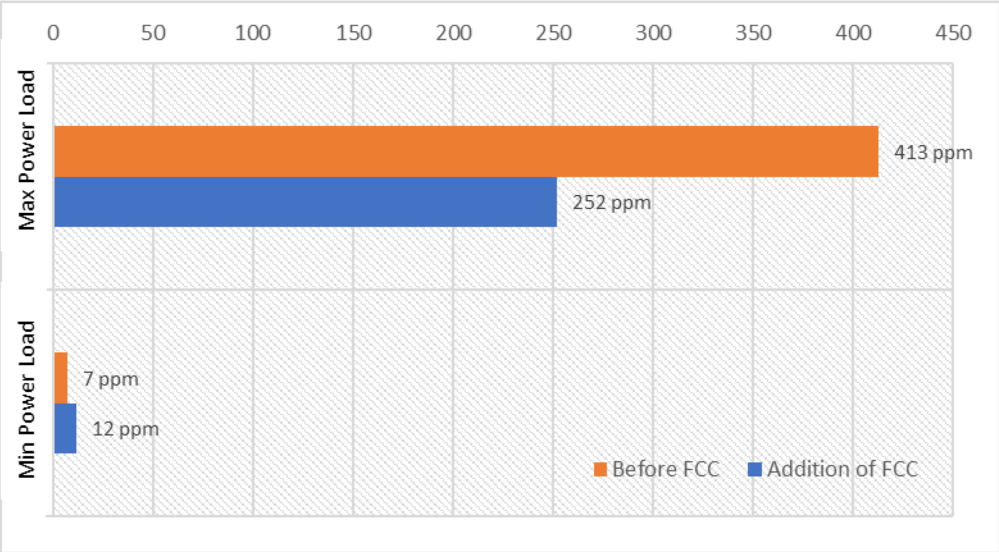
The emissions of CO before and after addition of FCC into the fuel is summarised in Table 4.1 below:

Table 4.1: Emissions of CO from Mitsubishi Trition's Exhaust Gas

Vehicle Operation Mode	Speed (RPM)	Before addition of FCC		After addition of FCC	
		Temp. (°C)	CO (ppm)	Temp. (°C)	CO (ppm)
Minimum Rated Power (idle)	650	75	7	55	12
Maximum Rated Power (high idle)	2,500	78	413	75	252

The results are depicted in Figure 4.1 below:

Figure 4.1: Emissions of CO from Mitsubishi Trition's Exhaust Gas Plot



4.2 NITROGEN OXIDE

4.2.1 DEFINITION

Nitrogen oxides (NOx), the term used to describe the sum of NO, nitrogen dioxide (NO_2), and other oxides of nitrogen (NOx = NO + NO_2).

These gaseous pollutants are produced under very high pressure and temperature conditions in an engine when nitrogen and oxygen in the air combines to form nitrous oxide, nitrogen dioxide and nitrogen oxide. NO makes up the largest content of NOx.

4.2.2 ANALYSIS

Based on the emissions test report (Att. 1), Mitsubishi Trition running at minimum rated power (idle) produces NOx in the exhaust at a concentration of 130 ppm before addition of FCC. With addition of FCC, the NOx emissions are significantly reduced by 79% from 130 ppm to 27 ppm. As NOx increases with excess oxygen, which occurs under lean fuel conditions and higher combustion temperatures, addition of FCC which appeared to have lowered the exhaust temperature from 75°C to 55°C would assisted in reduction of NOx emission.

With vehicle running at maximum rated power, the NOx concentration in exhaust gas emission is 151 ppm before addition of FCC and with addition of FCC, the emissions are reduced by 10% to 136 ppm.

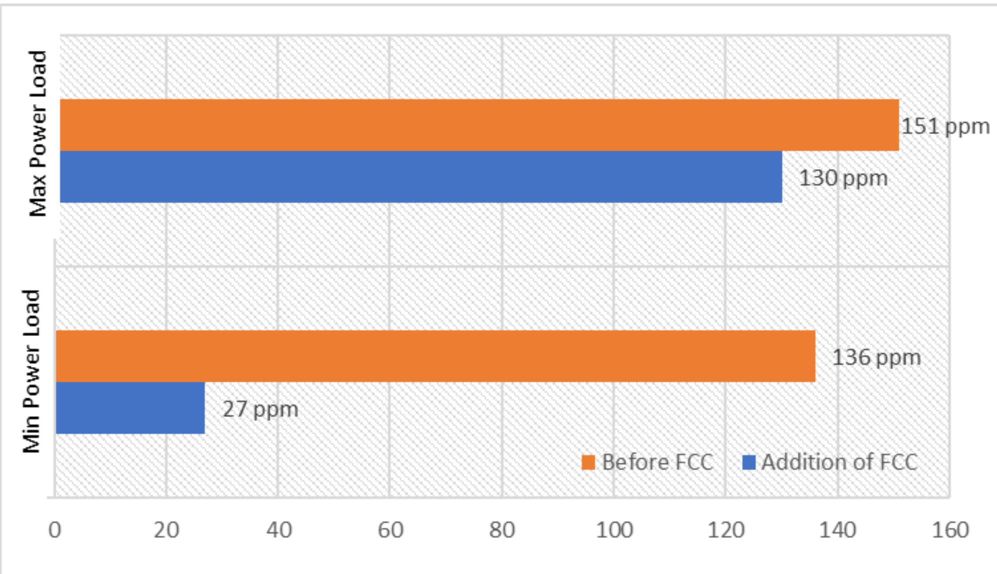
The emissions of NOx before and after addition of FCC into the fuel is summarised in Table 4.2 below:

Table 4.2: Emissions of NOx from Mitsubishi Trition's Exhaust

Vehicle Operation Mode	Speed (RPM)	Before addition of FCC		After addition of FCC	
		Temp. (°C)	NOx (ppm)	Temp. (°C)	NOx (ppm)
Minimum Rated Power (idle)	650	75	130	55	27
Maximum Rated Power (high idle)	2,500	78	151	75	136

Emissions of NOx is ranked No. 1 in the National Pollution Inventory Risk Ranking with the highest environmental hazard factor (Ref. 7). Hence, reduction in emissions of NOx is a highly beneficial for the environment. The results are depicted in Figure 4.2 below:

Figure 4.2: Emissions of NOx from Mitsubishi Trition's Exhaust Gas Plot



5 SUMMARY

Pollutant		Description	Impact / Adverse Effects	Maximum (ambient) concentration	Emissions before FCC (ppm)	Emissions after FCC (ppm)	Remarks / Conclusion
CO	Carbon Monoxide	Carbon monoxide (CO) is generated from combustion process as a component of motor vehicle exhaust. This gaseous pollutant is produced when there is insufficient oxygen present in the combustion chamber which results in a partially oxidised fuel.	CO's toxicity stems from its ability to reduce the oxygen-carrying capacity of blood by preferentially bonding to haemoglobin and impacts human health.	1,500 ppm (Att. 1) / 9.0 ppm per 8 hours (average period) (Att. 2)	Min: 7 Max: 413	Min: 12 Max: 252	A substantial 30% reduction of CO emissions at maximum rated power.
NOx	Nitrogen Oxide	Nitrogen oxides (NOx), the term used to describe the sum of NO, nitrogen dioxide (NO_2), and other oxides of nitrogen. NOx is the sum of NO and NO_2 contents in exhaust gas (NOx = NO + NO_2).	While NO is non-toxic by itself, it contributes to ozone formation. "NO2 can irritate the lungs and lower resistance to respiratory infection…" (Ref. 6). Under some conditions, NOx is also an important precursor to particulate matter (Ref. 2), haze and acid rain.	1,000 ppm (Att. 1) / 0.12 ppm per hour (average period) / 0.03 per year (average period) (Att. 2)	Min: 130 Max: 151	Min: 27 Max: 136	A notable significant 79% reduction of NOx emissions at minimum rated power and a 10% reduction of NOx emissions at maximum rated power.
NO	Nitric Oxide	NO makes up the largest content in exhaust gas (Ref. 4).			Min: 123 Max: 147	Min: 27 Max: 135	
NO_2	Nitrogen Dioxide	NO_2 in proportion 5-10% of NO (Ref. 4).			Min: 7 Max: 4	Min: 0 Max: 1	

Revision A

Emissions Report – Toyota Corolla

ADDF-REP-TA-0005

Michelle Lam

EMISSIONS REPORT – TOYOTA COROLLA

ADDF-REP-TA-0005

Revision Number: A
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1 EXECUTIVE SUMMARY

The major air pollutants are caused by emissions of exhaust from motor vehicles which are principal source that emits nitrogen oxides (NOx), carbon monoxide (CO) and sulfur dioxide (SO_2) in most capital cities worldwide. These ambient air pollutants, CO, NOx and SO_2 are part of the main concern pollutants as listed in the 1998 Ambient Air Quality National Environmental Protection Measure (Ambient Air Quality NEPM) and are all in top 3 ranks in the National Pollution Inventory Risk Ranking. The pollutants are of major concern as they pose different levels of risk to human health and adversely impacts the environment.

With regards to lowering and limiting these harmful vehicle emissions, Fuel Conditioner Concentrate (FCC), FCC is a non-hydrocarbon fuel conditioner that assists in achieving clean fuel, improves performance and increasing fuel efficiency, whilst most importantly lowering emissions of air pollutants.

Key summary based on the technical analysis of the emissions from Toyota Corolla (Att. 1) with vehicle running on fuel without FCC additive (benchmark) and with addition of FCC:

CO emissions:

- Emissions of CO pollutant is ranked at No. 3 in the National Pollution Inventory Risk Ranking with a high health hazard factor (Ref. 7).
- A substantial 97% reduction of CO emissions at maximum rated power which reduces the CO concentration from 37 ppm to 1 ppm (5 minutes average time) after addition of FCC.

SO_2 emissions:

- Emissions of SO_2 pollutant is ranked at No. 3 in the National Pollution Inventory Risk Ranking (Ref. 7).
- A 4% reduction of SO_2 emissions at minimum rated power which reduces the NOx concentration from 0.00098 to 0.00094 g/min after addition of FCC.

NOx emissions:

- Emissions of NOx pollutant is ranked highest i.e. No. 1 in the National Pollution Inventory Risk Ranking with the highest environmental hazard factor (Ref. 7).
- A 4% reduction of NOx emissions at minimum rated power which reduces the NOx concentration from 0.00077 to 0.00074 g/min after addition of FCC.

2 INTRODUCTION

The major air pollutants are caused by emissions of exhaust from motor vehicles which are principal source that emits nitrogen oxides, sulfur dioxide and carbon monoxide in most capital cities worldwide. Traffic contributes more than 75% of carbon monoxide emissions and most emissions of nitrogen oxides (Ref. 7).

Statistics for Australia capital cities for year 2000–01 indicates that motor vehicles are estimated to have contributed 47% of nitrogen oxide levels in Perth and 82% in Southeast Queensland. Motor vehicles are estimated to be the source of more than 60% of carbon monoxide levels for all capital city airsheds other than Darwin (Ref. 7).

These air pollutants pose different levels of risk to human health and adversely impacts the environment. The ambient air pollutants of most concern in Australia are listed in the 1998 Ambient Air Quality National Environmental Protection Measure (Ambient Air Quality NEPM) which are carbon monoxide, nitrogen oxides, volatile organic compounds, lead, sulfur dioxide and particulate matter of less than 10 microns (PM10).

In environmental view of limiting harmful vehicle emissions, FCC is a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency.

2.1 BACKGROUND

FCC is a blend of blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today’s high performance engines. The Primary benefits of FCC are:

- Solubilises liquid water into the fuel.
- Reduces or eliminates the conditions favourable to the growth of microorganisms.
- Stabilises fuel by inhibiting the formation of gums and varnish.
- Inhibits corrosion of fuel system components.
- Promotes a uniform fuel spray pattern in combustion chambers, thus reducing carbonisation and improving combustion efficiency.
- Inhibits formation of corrosive acids in combustion chambers.

2.2 DOCUMENT SCOPE

This document scope provides technical analysis for comparison of emissions from vehicle type Toyota Corolla running on fuel before and after addition of fuel additive, herein referred to as FCC. Analysis is made on emissions of major pollutants as listed below:

- Carbon Monoxide,
- Sulfur Dioxide and
- Nitrogen Dioxide.

2.3 AIR QUALITY STANDARD

The ambient air pollutants of most concern in Australia are listed in the 1998 Ambient Air Quality National Environmental Protection Measure (Ambient Air Quality NEPM) and the National Air Quality Standard is summarised in Table 2.1 (Att. 2):

Table 2.1: Australia National Air Quality Standard

Pollutant	Averaging Period	Maximum (ambient) concentration
Carbon monoxide	8 hours	9.0 ppm
Nitrogen dioxide	1 hour	0.12 ppm
	1 year	0.03 ppm
Sulfur dioxide	1 hour	0.20 ppm
	1 day	0.08 ppm
	1 year	0.02 ppm
Photochemical oxidants (as ozone)	1 hour	0.10 ppm
	4 hours	0.08 ppm
Lead	1 year	0.50 µg/m³
Particles as PM10	1 day	50 µg/m³

2.4 POLLUTANT INVENTORY RISK RANKING

The National Environment Protection Council Technical Advisory Panel (formed to recommend substances for inclusion in the National Pollutant Inventory to assessed the risks to human health and the environment from exposure to a substance listed in the inventory) risk assessments for the major air pollutants are summarised in Table 2.1.

Table 2.1 National Pollutant Inventory Risk Ranking (Selected Air Pollutants (Ref. 7))

Pollutant	*Health hazard*	*Environmental hazard*	*Combined rank*	*National Pollution Inventory rank*[1]
Nitrogen oxides—N_2O NO NO_2	1.5	3.0	4.5	1
Carbon monoxide—CO	2.0	0.8	2.8	3
Sulfur dioxide—SO_2	1.5	1.3	2.8	3
PM_{10}	1.2	1.3	2.5	7
Lead and compounds	1.7	1.5	3.2	11
Non-methane volatile organic compounds				
Xylene	1.3	1.0	2.3	9
Benzene	2.3	1.0	3.3	14
Toluene	1.3	1.3	2.6	33

Notes The approach used to assess pollutants results in some substances receiving the same National Pollution Inventory rank. This ranking also considers human exposure to the pollutant. Excluded from the National Environment Protection Council list of approximately 400 substances were substances that had been banned or scheduled for phase-out, agriculture and veterinary chemicals, and those substances where other reporting was in place because of their ozone depleting or greenhouse effects.

Source National Pollution Inventory Technical Advisory Panel (1999); National Pollution Inventory substance profiles (Environment Australia undated).

3 ABBREVIATIONS & DEFINITIONS

3.1 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ADR	Australia Design Rules (Control of Vehicle Emissions)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EPA	Environmental Protection Agency
FCC	Fuel Conditioner Concentrate
H_2O	Water
NOx	Nitrogen Oxide
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
PM	Particulate Matter
SO_2	Sulfur Dioxide
VOC	Volatile Organic Compound

3.2 POLLUTANT DESCRIPTION

The major pollutant assessed and its' adverse effects on human health and environment are described and summarised as below:

Pollutant		Description	Impact / Adverse Effects
CO	Carbon Monoxide	Carbon monoxide (CO) is generated from combustion process as a component of motor vehicle exhaust. This gaseous pollutant is produced when there is insufficient oxygen present in the combustion chamber which results in a partially oxidised fuel.	CO's toxicity stems from its ability to reduce the oxygen-carrying capacity of blood by preferentially bonding to haemoglobin and impacts human health.
SO_2	Sulfur Dioxide	Sulfur dioxide has a nasty, sharp smell generated from combustion process as a component of motor vehicle exhaust. It reacts easily with other substances to form harmful compounds, such as sulfuric acid, sulfurous acid and sulfate particles.	Minimum concentrations of sulfur dioxide can cause adverse health effects as it attacks the throat and lungs. Most people would feel the worst symptoms in 10 or 15 minutes after breathing it in.People with breathing problems can suffer severe illness.

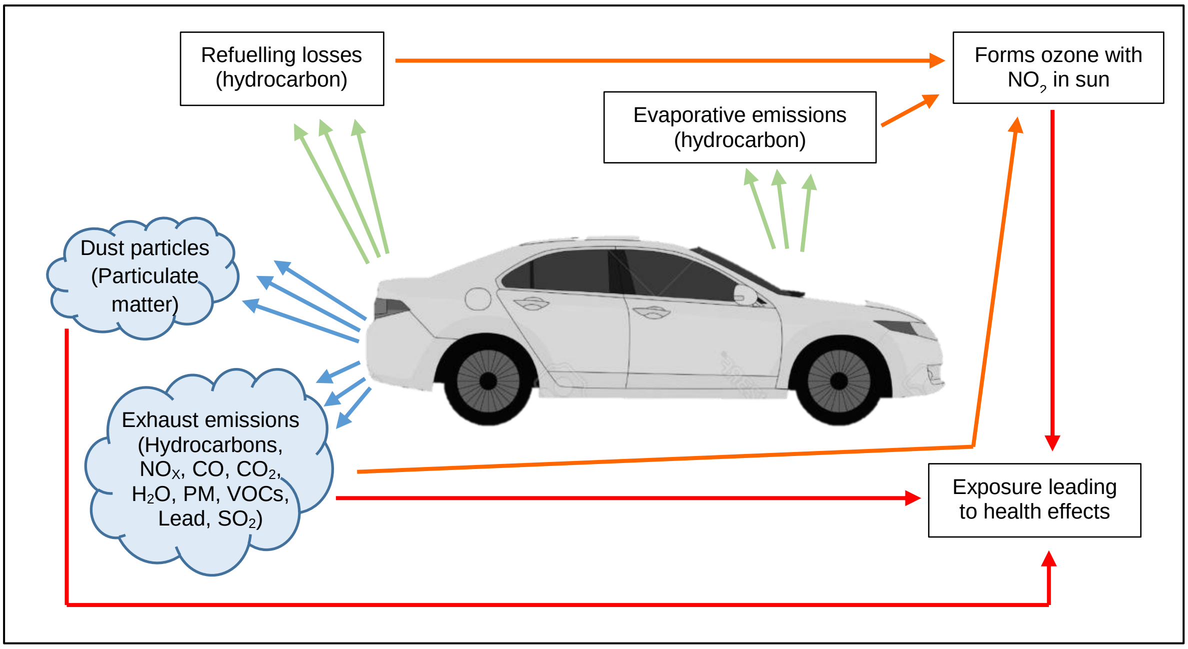
Pollutant		Description	Impact / Adverse Effects
NOx	Nitrogen Oxide	Nitrogen oxides (NOx), the term used to describe the sum of NO, nitrogen dioxide (NO_2), and other oxides of nitrogen. NOx is the sum of NO and NO_2 contents in exhaust gas (NOx = NO + NO_2).	While NO is non-toxic by itself, it contributes to ozone formation. "NO_2 can irritate the lungs and lower resistance to respiratory infection…" (Ref. 6). Under some conditions, NOx is also an important precursor to particulate matter (Ref. 2), haze and acid rain.
NO	Nitric Oxide	NO makes up the largest content / contributor in exhaust gas (Ref. 4).	
NO_2	Nitrogen Dioxide	NO_2 in proportion 5-10% of NO (Ref. 4).	

3.3 VEHICLE EMISSIONS AND HEALTH EFFECTS

Pollutants are formed during the combustion process in the vehicle's engine. There is no direct relationship between regulated pollutants produced by the engine, tailpipe emissions of these pollutants, and vehicle mass or size.

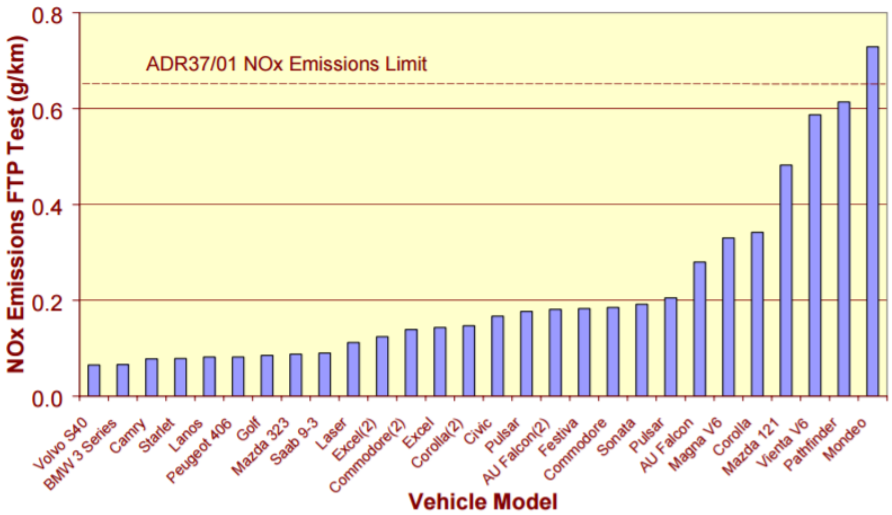
Non-combustion sources of ambient air pollution can include the evaporation of the fuel itself and vehicle movement can generate emissions of road dust and brake lining dust. The impact on human health from vehicle emissions are summarised in Figure 3.1:

Figure 3.1: Transport emissions and health effects



In Australia performance-based standards limit the amount of specific air pollutants that may be emitted by new vehicles. Each new vehicle model is required to comply with Australian Design Rules (Australian Design Rules are national standards under the Motor Vehicle Standards Act 1989) before it is supplied to the Australian market. Nitrogen Oxide emissions ADR37/01 Vehicles (Australia Design Rules compliance vehicles) are included in Figure 3.2 for emissions of CO for various vehicle make.

Figure 3.2: Nitrogen Oxide Emissions from ADR37/01 Vehicles on the ADR37/01 Test (Ref. 7)



Note Most vehicles in the Comparative Vehicle Emissions Study were designed to comply with ADR37/01.

Source Australian Government Department of Transport and Regional Services 2001

3.4 REFERENCES

The references used in this document are:

1. Vehicle Exhaust Gas Analysis (Job number 1617-153), 23-Jan-2017 and 25-Jan-2015 (Att. 1).
2. Diesel Fuel Technical Review, Chevron.
3. https://www.environment.gov.au/protection/air-quality/air-quality-standards
4. http://fluid.wme.pwr.wroc.pl/~spalanie/dydaktyka/combustion_en/NOx/NOx_formation.pdf
5. Clean Coal Engineering Technology, Miller, Bruce G., 2011
6. “Air Trends, September 2003 Report: National Air Quality and Emissions Trends Report, 2003 Special Studies Edition,” U.S. EPA, http://www.epa.gov/air/airtrends/aqtrnd03/
7. Health impacts of transport emissions in Australia: Economic costs, Australia Government, Department of Transport and Regional Services (https://bitre.gov.au/publications/2005/files/wp_063.pdf)
8. https://www.environment.gov.au/protection/publications/factsheet-sulfur-dioxide-so2

3.5 ATTACHMENTS

1. Emission Assessment, Vehicle Exhaust Gas Analysis (Job number 1617-153) (before addition of FCC and after addition of FCC) 23-Jan-2017 and 25-Jan-2017.
2. Australia Government Department of Environmental and Energy, Air Quality Standards in Australia.

4 EMISSIONS

The emissions from Toyota Corolla (Attachment 1) with specifications as below are assessed with vehicle running on fuel without FCC additive (benchmark) and with addition of FCC. The Toyota Corolla exhaust gas emission data is recorded at vehicle's minimum rated power (Run 1 - idle) and at maximum rated power (Run 2 – 3,000 RPM).

Description	Data
Unit & Engine Make	Toyota
Registration No.	1GCR 137
Model	Corolla 2016
Exhaust ID	51.46 mm

4.1 CARBON MONOXIDE (CO)

4.1.1 DESCRIPTION

Carbon monoxide (CO) is generated from combustion process as a component of motor vehicle exhaust. This gaseous pollutant is produced when there is insufficient oxygen present in the combustion chamber which results in a partially oxidised fuel. High levels of carbon monoxide can be caused by a too rich fuel mixture, incorrect idle speed, faulty air cleaner or positive crankcase ventilation (PCV) valve, incorrect fuel pressure or faulty carburettor/injection system.

4.1.2 ANALYSIS

Based on the emissions test report (Att. 1), Toyota Corolla running at minimum rated power (idle) produces CO in the exhaust at a concentration of 1 ppm and increases slightly to 2.4 ppm with addition of FCC. This is a minimal 1.4 ppm increase and considering that the vehicle is idle, this concentration of emission is insignificant in comparison to emissions from vehicle running at normal load.

With vehicle running at 3,000 RPM, the CO concentration in exhaust gas emission is 37 ppm before addition of FCC and with addition of FCC, the CO emission is significantly reduced by **97%** to less than 1 ppm.

The emissions of CO before and after addition of FCC into the fuel is summarised in Table 4.1 below:

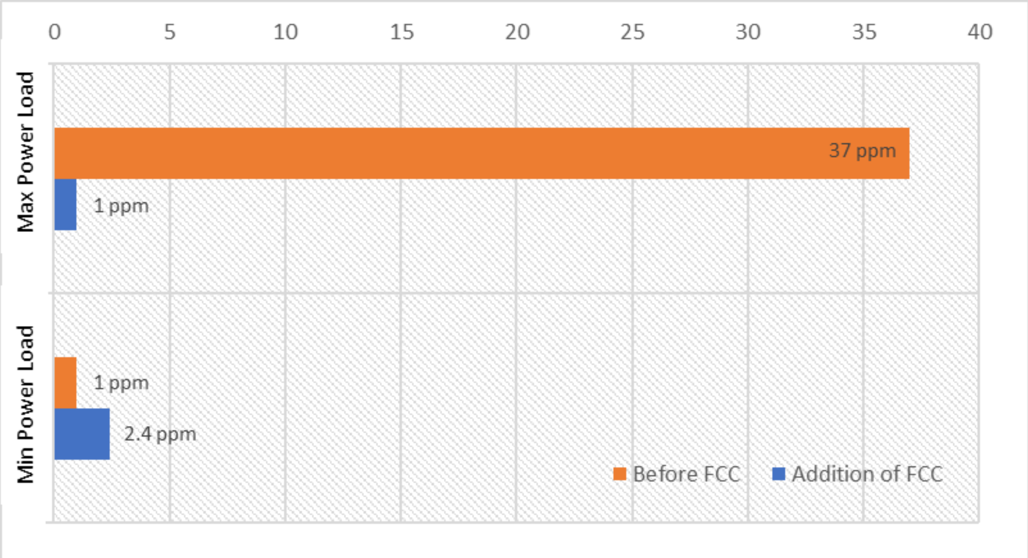
Table 4.1: Emissions of CO from Toyota Corolla's Exhaust Gas

Vehicle Operation Mode	Speed (RPM)	Before addition of FCC		After addition of FCC	
		Temp. (°C)	CO (ppm)	Temp. (°C)	CO (ppm)
Minimum Rated Power (idle)	-	116.2	1	99.8	2.4
Maximum Rated Power	3,000	180	37	228	< 1

Emissions of CO is ranked No. 3 in the National Pollution Inventory Risk Ranking with a high health hazard factor (Ref. 7).

The results are depicted in Figure 4.1 in the following page:

Figure 4.1: Emissions of CO from Toyota Corolla's Exhaust Gas Plot



4.2 SULFUR DIOXIDE

4.2.1 DEFINITION

Sulfur dioxide is generated from combustion process as a component of motor vehicle exhaust. It reacts easily with other substances to form harmful compounds, such as sulfuric acid, sulfurous acid and sulfate particles.

4.2.2 ANALYSIS

Based on the emissions test report (Att. 1), Toyota Corolla running at minimum rated power (idle) produces SO_2 in the exhaust at a concentration of 0.00098 g/min before addition of FCC. With addition of FCC, the SO_2 emissions are reduced by 4% to 0.00094 g/min.

With vehicle running at maximum rated power, the SO_2 concentration in exhaust gas emission is < 0.0019 g/min before addition of FCC and with addition of FCC, the emissions minimally increase to < 0.0020 g/min.

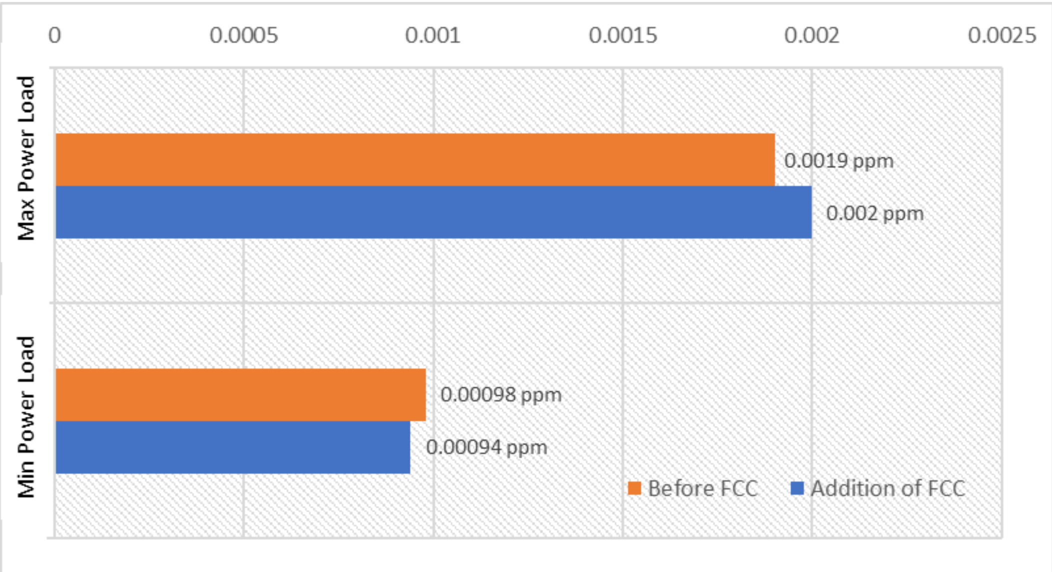
The emissions of SO_2 before and after addition of FCC into the fuel is summarised in Table 4.3 below:

Table 4.2: Emissions of SO_2 from Toyota Corolla's Exhaust Gas

Vehicle Operation Mode	Speed (RPM)	Before addition of FCC		After addition of FCC	
		Temp. (°C)	SO_2 (ppm)	Temp. (°C)	SO_2 (ppm)
Minimum Rated Power (idle)	-	116.2	0.00098	99.8	0.00094
Maximum Rated Power	3,000	180	< 0.0019	228	< 0.0020

The results are depicted in Figure 4.3 below:

Figure 4.2: Emissions of SO_2 from Toyota Corolla's Exhaust Gas Plot



4.3 NITROGEN OXIDE

4.3.1 DEFINITION

Nitrogen oxides (NOx), the term used to describe the sum of NO, nitrogen dioxide (NO_2), and other oxides of nitrogen (NOx = NO + NO_2).

These gaseous pollutants are produced under very high pressure and temperature conditions in an engine when nitrogen and oxygen in the air combines to form nitrous oxide, nitrogen dioxide and nitrogen oxide. NO makes up the largest content of NOx.

4.3.2 ANALYSIS

Based on the emissions test report (Att. 1), Toyota Corolla running at minimum rated power (idle) produces NOx in the exhaust at a concentration of 0.00077 g/min before addition of FCC. With addition of FCC, the NOx emissions are reduced by 4% to 0.00074 g/min. As NOx increases with excess oxygen, which occurs under lean fuel conditions and higher combustion temperatures, addition of FCC which appeared to have lowered the exhaust temperature from 116.2°C to 99.8°C would assisted in reduction of NOx emission.

With vehicle running at maximum rated power, the NOx concentration in exhaust gas emission is < 0.0015 g/min before addition of FCC and with addition of FCC, the emissions minimally increase to < 0.0016 g/min.

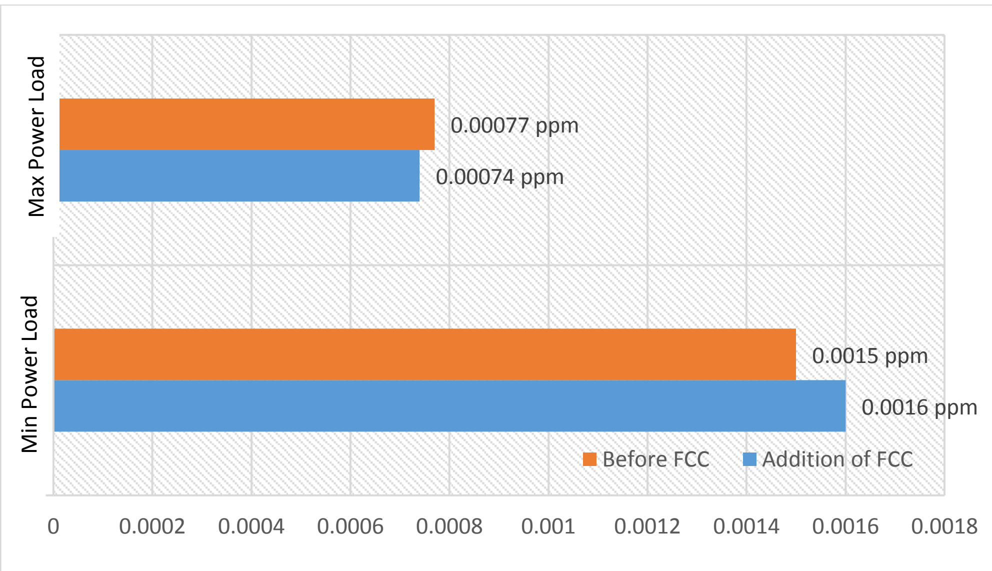
The emissions of NOx before and after addition of FCC into the fuel is summarised in Table 4.3 below:

Table 4.3: Emissions of NOx from Toyota Corolla's Exhaust Gas

Vehicle Operation Mode	Speed (RPM)	Before addition of FCC		After addition of FCC	
		Temp. (°C)	NOx (g/min)	Temp. (°C)	NOx (g/min)
Minimum Rated Power (idle)	-	116.2	0.00077	99.8	0.00074
Maximum Rated Power	3,000	180	< 0.0015	228	< 0.0016

The results are depicted in Figure 4.3 below:

Figure 4.3: Emissions of NOx from Toyota Corolla's Exhaust Gas Plot



5 SUMMARY

Pollutant		Description	Impact / Adverse Effects	Maximum (ambient) concentration	Emissions before FCC	Emissions after FCC	Remarks / Conclusion
CO	Carbon Monoxide	Carbon monoxide (CO) is generated from combustion process as a component of motor vehicle exhaust. This gaseous pollutant is produced when there is insufficient oxygen present in the combustion chamber which results in a partially oxidised fuel.	CO's toxicity stems from its ability to reduce the oxygen-carrying capacity of blood by preferentially bonding to haemoglobin and impacts human health.	9.0 ppm per 8 hours (average period) (Att. 2)	Idle: 1 ppm Max: 37 ppm	Idle: 2.4 ppm Max: 1 ppm	A substantial 97% reduction of CO emissions at maximum rated power.
SO_2	Sulfur Dioxide	Sulfur dioxide has a nasty, sharp smell generated from combustion process as a component of motor vehicle exhaust. It reacts easily with other substances to form harmful compounds, such as sulfuric acid, sulfurous acid and sulfate particles.	Sulfur dioxide irritates the nose, throat, and airways to cause coughing, wheezing, shortness of breath, or a tight feeling around the chest and most people would feel the worst symptoms in 10 or 15 minutes after breathing it in. Those most at risk of developing problems if they are exposed to sulfur dioxide are people with asthma or similar conditions.	0.20 ppm per hour (average period) (Att. 2)	Idle: 0.00098 g/min (<1 ppm per 5 mins) Max: 0.0019 g/min (<1 ppm per 5 mins)	Idle: 0.00094 g/min (<1 ppm per 5 mins) Max: 0.0020 g/min (<1 ppm per 5 mins)	A 4% reduction of SO_2 emissions at vehicle idle condition.

Pollutant		**Description**	**Impact / Adverse Effects**	**Maximum (ambient) concentration**	**Emissions before FCC**	**Emissions after FCC**	**Remarks / Conclusion**
NOx	Nitrogen Oxide	Nitrogen oxides (NOx), the term used to describe the sum of NO, nitrogen dioxide (NO_2), and other oxides of nitrogen. NOx is the sum of NO and NO_2 contents in exhaust gas (NOx = NO + NO_2).	While NO is non-toxic by itself, it contributes to ozone formation. "NO2 can irritate the lungs and lower resistance to respiratory infection…" (Ref. 6). Under some conditions, NOx is also an important precursor to particulate matter (Ref. 2), haze and acid rain.	0.12 ppm per hour (average period) / 0.03 per year (average period) (Att. 2)	Idle: 0.00077 g/min (<1 ppm per 5 mins) Max: 0.0015 g/min (<1.1 ppm per 5 mins)	Idle: 0.00074 g/min (<1 ppm per 5 mins) Max: 0.0016 g/min (<1.1 ppm per 5 mins)	A 4% reduction of NOx emissions at vehicle idle condition.
NO	Nitric Oxide	NO makes up the largest content in exhaust gas (Ref. 4).					
NO_2	Nitrogen Dioxide	NO_2 in proportion 5-10% of NO (Ref. 4).					

Executive Summary and Technical Report

Exhaust Gas Analysis – Ford F350

By

Nicole SY Liau (MIChemE, CEng)

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EXECUTIVE SUMMARY

FCC is a fuel conditioner produced by ADDFUEL PTY LTD which is a blend of surfactants (detergents), oxygenates and corrosion inhibitors (refer MSDS in Attachment 3) developed to improve fuel efficiency and saving the maintenance costs through cleaner and better combustion process. It's a non-hydrocarbon fuel conditioner that may clean fuel and improves performance whilst lowering pollutants emission to the environment.

During recent exhaust gas analysis carried out on the Ford F350, results in Figure 1 show significant reduction in carbon monoxide (CO) which is nearly 65% lesser CO was detected. It is however observed that oxides of nitrogen (NOx) has increased due to the oxygenate effect of the fuel additive.

Carbon monoxide is a toxic, colourless and odourless gas. It affects healthy and unhealthy people. Increased levels of carbon monoxide reduce the amount of oxygen carried by haemoglobin around the body in red blood cells. The result is that vital organs, such as the brain, nervous tissues and the heart, do not receive enough oxygen to work properly. No more than 2.5% of haemoglobin can be bound to carbon monoxide before some health effects become noticeable. At very high concentrations of carbon monoxide, up to 40% of the haemoglobin can be bound to carbon monoxide in this way. This level will almost certainly kill humans.

NOx is produced from the reaction of nitrogen and oxygen gases during combustion especially at higher temperatures. The two elements combine to form nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide is not considered to be hazardous to health at typical ambient concentration but nitrogen dioxide can be. As shown in Figure 2b, the increment was mainly contributed by nitric oxide (NO) which is not considered harmful at a typical condition. Therefore the increase amount of NO may not be a critical issue.

As the Australia Government has taken steps to manage and reduce the amount of CO emissions to the environment including implementation of tighter vehicle emission standard, hence using FCC fuel additive could be considered beneficial to achieve cleaner burning of the vehicle's engine.

TECHNICAL REPORT FOR FORD F350 EXHAUST GAS ANALYSIS

On 20 December 2016, exhaust gas analysis was carried on Ford F350 model to investigate the benefit of using FCC, particularly to the improvement of reducing vehicle emissions. The car was powered by diesel and the FCC was added on 4000:1 ratio. Tests were run on a range of rated power i.e.: from minimum 500 rpm to maximum of 2,000 and 3,000 rpm. The minimum rated power was carried to investigate the initial conditions. Two maximum rated powers were investigated to identify the optimum performance speed of the vehicle.

The undiluted exhaust gas limit is set at 1,500 ppm CO and 1,000 NOx. The exhaust gas was diluted in a control volume before the emissions concentration was recorded. The test results of the vehicle emissions before and after the FCC fuel additive was added were recorded in Attachment 1 and 2 respectively.

Carbon Monoxide (CO) Emission

The emission of carbon monoxide (CO) before and after the FCC was added had been investigated and recorded. The CO emission trends are presented graphically in Figure 1, extracted from results obtained from the lab test reports in Attachment 1 and 2.

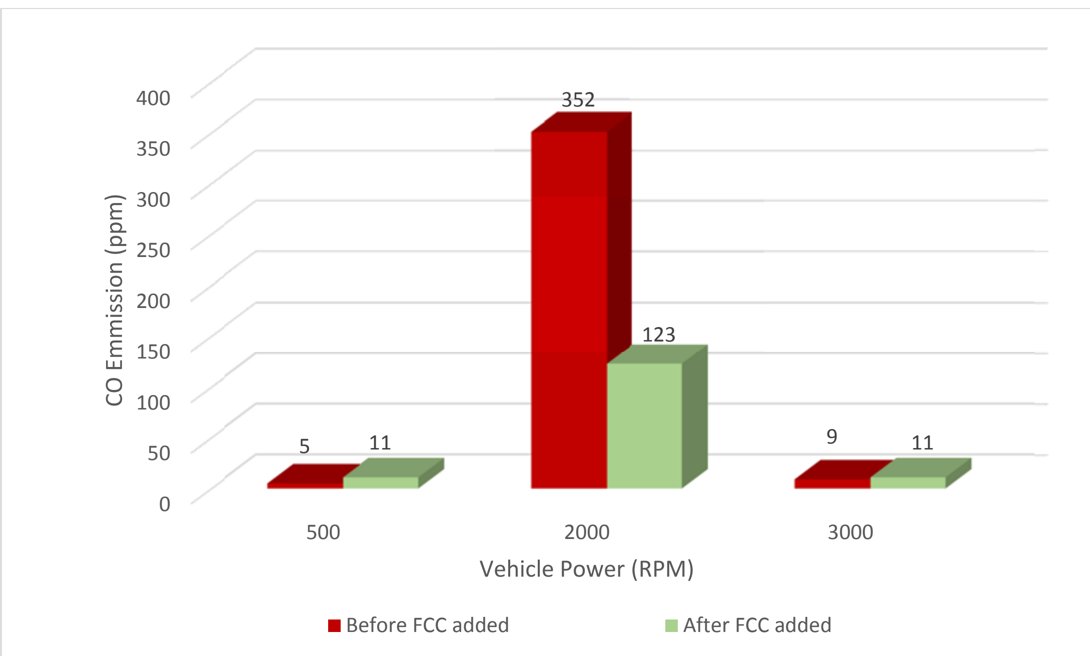

Figure 1: Ford F350 - CO Emission Before and After FCC was added

Figure 1 shows the CO emission in the exhaust gas before and after the FCC additive, measure in part per million, during both minimum and maximum engine speeds

At the beginning, when the engine was running at minimum idling speed of 500 rpm, there was no reduction of CO emission was observed. It could be due to unstable state of the vehicle. When the vehicle was ramped up to its optimum maximum idling speed of 2,000 rpm, significant CO emission reduction was observed i.e.: approximately 65% after the FCC was added. Whereas, no CO reduction was observed when the vehicle ramped up to 3,000 ppm at its upper limit. The results have demonstrated that using FCC additive under the vehicle optimum speed limit could effectively reduce the CO emission from the exhaust gas.

The oxygenated chemical compound i.e.: alkoxy propanols (refer MSDS in Attachment 3) within the FCC contains oxygen as a part of their chemical structure. The exhaust emissions such as CO and HC level were progressively reduced as oxygen content is increased.

Oxide of Nitrogen (NOx) Emission

The graphical summary of the NOx emission is presented in Figure 2a and 2b below.

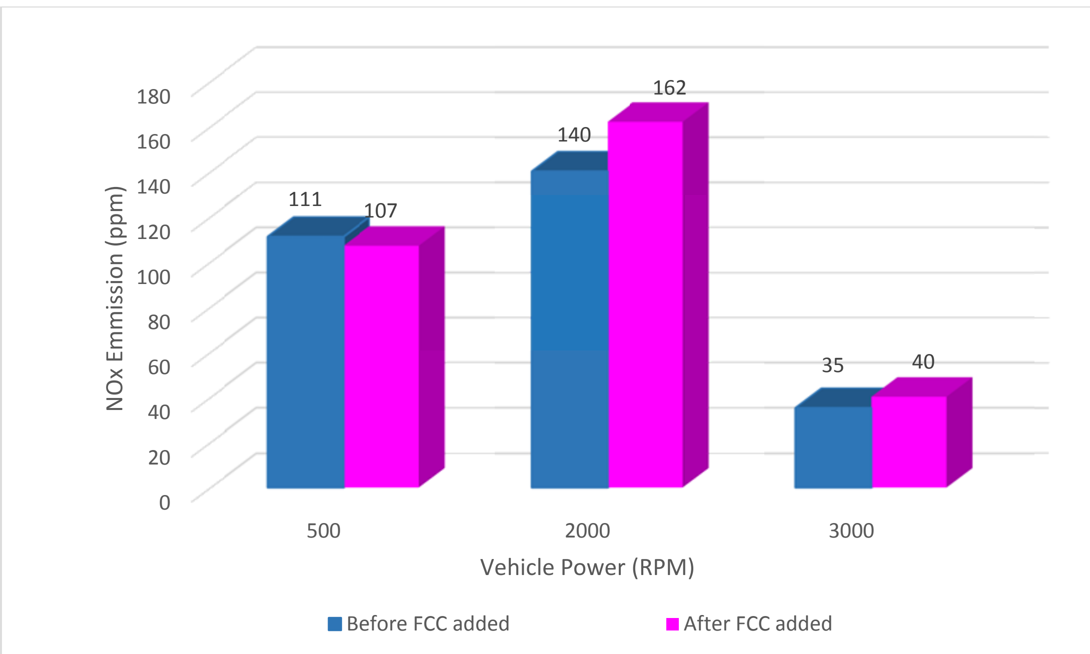

Figure 2a: Ford F350 - NOx Emission Before and After FCC was added

Figure 2a compares NOx emission before and after FCC additive was added during both minimum and maximum rated power, in part per million. A slight reduction of NOx emissions was observed during the minimum idling speed of 500 rpm after FCC was added. However approximately 15% increment of NOx was observed during maximum idling speed of 2,000 and 3,000 rpm.

The element of NOx that released to atmosphere were also recorded and graphically presented as below:

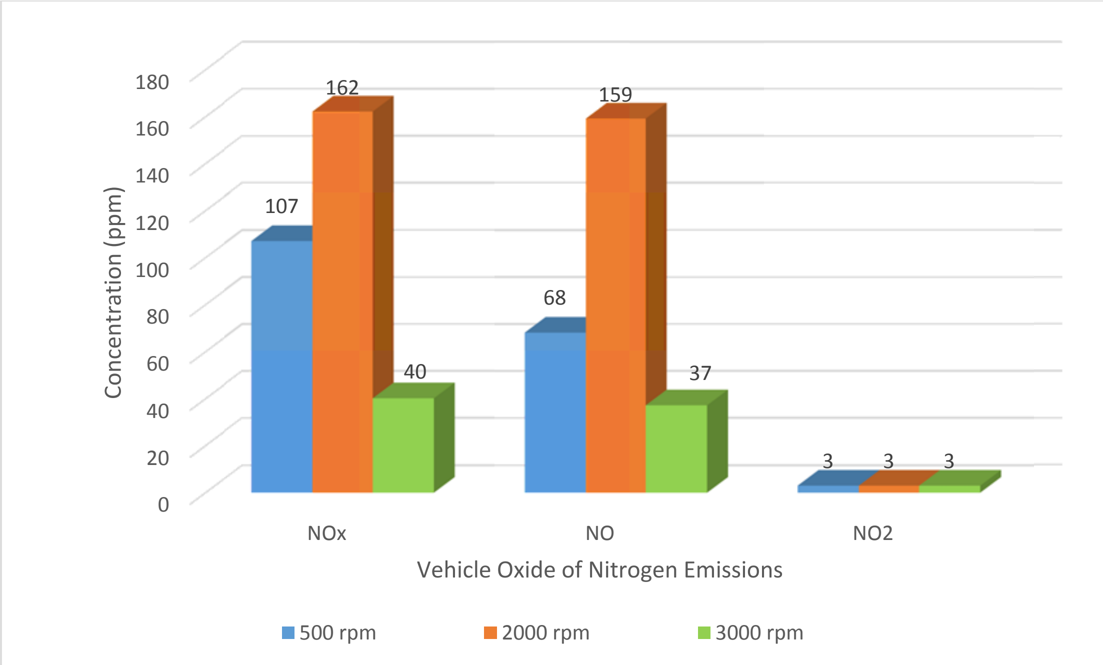

Figure 2b: Ford F350 – NOx Element Emissions After FCC was added

NOx is produced during the combustion process when nitrogen and oxygen are present at elevated temperatures. At high temperatures, they undergo an endothermic reaction producing various oxides of nitrogen. Such temperatures can arise inside an internal combustion engine, particularly diesel engine within the vehicle as it run at higher compression ratios. The two elements combine to form nitric oxide (NO) and nitrogen dioxide (NO_2). Nitric oxide is not considered to be hazardous to health at typical ambient concentration but nitrogen dioxide can be. As shown in Figure 2b, the increment was mainly contributed by nitric oxide (NO) which is not considered harmful at a typical condition. Therefore the increase amount of NO may not be a critical issue.

In brief, the significant reduction in CO (as shown in Figure 1) is deemed outweigh the disadvantage from the increase of NOx because:

1. The increment is relatively trivial compared to the advantage of greatly minimising CO emission to the atmosphere as high level of carbon monoxide CO is poisonous to humans.
2. Figure 2b also shows that the majority of NOx increment was contributed by NO which is considered not harmful at a typical ambient concentration.

ATTACHMENT 1 – EXHAUST GAS ANALYSIS BEFORE FUEL ADDITIVE

consulting & contracting engineers

www.rapallo.com.au ABN: 31 726 506 590 ACN: 009 257 836

CERTIFICATE OF EXHAUST GAS ANALYSIS

SERIAL No. 1FTWW3BRXAEB04487

MINING COMPANY: N/A (emissions test before fuel additive) *TEST DATE: 11/12/2016*
UNIT OWNER: KENERIC Racing *EXPIRY DATE: 11/12/2017*

SITE CONTRACTOR OPERATING UNIT: N/A (emissions test before fuel additive)
NAME OF MINE/DECLINE: N/A (emissions test before fuel additive)
CONTACT PERSON: Stuart Martin (ADDFUEL)
PHONE: 0488 678 046 *FAX: TBA*

UNIT MAKE:	*Ford*	*REGO No.:*	*1DLR 701*
MODEL No:	*F350 Lariat Super Duty*	*ASSET No.:*	*N/A*
ENGINE MAKE:	*Ford*	*ENGINE No.:*	*1FTWW3BRXAEB04487*
ENGINE CAPACITY:	*6,700 cc*	*ENGINE kW:*	*324 kW (440hp)*
TOTAL HOURS/KM RUN:	*21,446 kms*	*ORIGINAL ENGINE:*	*Yes*

EXHAUST TREATMENT TYPE: Turbo Diesel Standard *BANK: V8*

ANALYSIS RESULTS

UNDILUTED EXHAUST GAS – Maximum level of exhaust gases permitted ; 1000ppm NOx 1500 ppm CO

ALTITUDE m	Rpm	TEMP °C	O2%	CO2%	Effg%	Effn%	CO ppm	NOx ppm	NO ppm	NO^2 ppm
Min Rated Power (idle)	500	65					5	111	107	4
Max Rated Power No Load (High idle)	2000	75					352	140	137	3
Max Rated Power No Load (High Idle)	3000	95					9	35	33	2

OPACITY TEST DATA

Opacity Meter calibrated before use (yes/no)?	-	*N/A*	
Average peak opacity registered at snap idle	-	*N/A*	*% Maximum Opacity 50%*
Average base opacity at idle	-	*N/A*	*%*
Speed of engine during snap idle test, if available?	-	*N/A*	*rpm*
Was opacity reading & procedure used representative?	-	*N/A*	
Location of test, Surface or Underground?	-	*Surface*	

EVALUATOR's NAME: S. Niederberger ***SIGNATURE:*** [signature]

COMMENTS: Results Acceptable ***DATE: 11/12/2016***

Notes: Effn% = overall efficiency of combustion system Effg% = efficiency of gases existing the exhaust related by ratios of CO2 to CO and O2 in the exhaust gases.

ATTACHMENT 2 – EXHAUST GAS ANALYSIS AFTER FUEL ADDITIVE

Rapallo
consulting & contracting engineers

CERTIFICATE OF EXHAUST GAS ANALYSIS

SERIAL No. 1FTWW3BRXAEB04487

MINING COMPANY: N/A (emissions test after fuel additive) *TEST DATE: 20/12/2016*
UNIT OWNER: Keneric Group Australia *EXPIRY DATE: 20/12/2017*

SITE CONTRACTOR OPERATING UNIT: N/A (emissions test after fuel additive)
NAME OF MINE/DECLINE: N/A (emissions test after fuel additive)
CONTACT PERSON: Stuart Martin (ADDFUEL)
PHONE: 0488 678 046 *FAX: TBA*

UNIT MAKE: Ford *REGO No.: 1DLR 701*
MODEL No: F350 Lariat Super Duty *ASSET No.: N/A*
ENGINE MAKE: Ford *ENGINE No.: 1FTWW3BRXAEB04487*
ENGINE CAPACITY: 6,700 cc *ENGINE kW: 324 kW (440hp)*
TOTAL HOURS/KM RUN: 24,090 kms *ORIGINAL ENGINE: Yes*

EXHAUST TREATMENT TYPE: Turbo Diesel Standard *BANK: V8*

ANALYSIS RESULTS

UNDILUTED EXHAUST GAS – Maximum level of exhaust gases permitted ; 1000ppm NOx 1500 ppm CO

ALTITUDE m	Rpm	TEMP °C	O2%	CO2%	Effg%	Effn%	CO ppm	NOx ppm	NO ppm	NO^2 ppm
Min Rated Power (idle) A/C off	500	51					40	89	88	0
Min Rated Power (idle) A/C on & pre rev	500	62					11	107	68	3
Max Rated Power No Load (High idle)	2000	75					123	162	159	3
Max Rated Power No Load (High Idle)	3000	125					11	40	37	3

OPACITY TEST DATA

Opacity Meter calibrated before use (yes/no)? - *N/A*
Average peak opacity registered at snap idle - *N/A % Maximum Opacity 50%*
Average base opacity at idle - *N/A %*
Speed of engine during snap idle test, if available? - *N/A rpm*
Was opacity reading & procedure used representative? - *N/A*
Location of test, Surface or Underground? - *Surface*

EVALUATOR's NAME: S. Niederberger ***SIGNATURE:***

COMMENTS: Results Acceptable ***DATE: 20/12/2016***

Notes: Effn% = overall efficiency of combustion system Effg% = efficiency of gases existing the exhaust related by ratios of CO2 to CO and O2 in the exhaust gases.

ATTACHMENT 3 – FCC MSDS

Material Safety Data Sheet

1. IDENTIFICATION of MATERIAL and SUPPLIER

Product Name:	**FUEL CONDITIONER CONCENTRATE**
Other Names:	FCC, Fuels Gold & Fuel Set EU
Recommended Use:	Fuel additive for petrol and Diesel fuels
Supplier:	**GND Holdings Pty Ltd trading as Choice Chem**
ABN:	**16 122 257 176**
Address:	**27 Boulder Road,** **Malaga Western Australia 6090**
Telephone:	**(618) 9248 9590**
Facsimile:	**(618) 9249 4810**
Emergency Telephone:	**+61 400 015 083**

2. HAZARDS IDENTIFICATION

Hazard Classification: This material is not considered **hazardous** according to the criteria of ASCC. However prolonged skin or eye contact can cause irritations.

Hazard Category: **N/A**

Risk Phrases: N/A

Safety Phrases: N/A

3. COMPOSITION/INFORMATION on INGREDIENTS

Chemical Name	CAS No	Proportion (%w/w)
Non Ionic surfactants (not considered hazardous)	N/A	30-60%
Alkoxy propanols		30-60%
Dye	Proprietary	<10%
Fragrance	Proprietary	<10%

4. FIRST AID MEASURES

FIRST AID

Swallowed: If swallowed, do NOT induce vomiting. Give a glass of water. Seek medical advice. For advice, contact a Poisons Information Centre (Phone Australia 131126) or a doctor.

Eye: If in eyes, hold eyelids apart and flush the eye continuously with running water. Continue flushing until advised to stop by the Poisons Information Centre or a doctor, or for at least 15 minutes.

Skin: If skin or hair contact occurs, remove contaminated clothing and flush skin and hair thoroughly with running water. Continue flushing until advised to stop by the Poisons Information Centre or a doctor.

Inhaled: Remove the victim from the source of exposure to fresh air. Avoid becoming a casualty. Seek medical advice if effects persist.

ADVICE TO DOCTOR Treat symptomatically.

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media:	Water spray, foam, carbon dioxide or dry chemical powder.
Fire / Explosion Hazard:	The product is a combustible liquid. Thermal decomposition may generate oxides of carbon.
Precautions for fire fighters and special protection equipment:	Fire Fighters should wear self-contained breathing apparatus to minimise the risk of exposure to the fumes.
Hazchem Code:	None

6. ACCIDENTAL RELEASE MEASURES

Spills: Spills are slippery. Ensure adequate ventilation. Avoid accidents, clean up immediately. Wear protective equipment to prevent skin and eye contamination. Contain the spill and prevent contamination into drains and waterways. Absorb with sand or other similar material. Collect and seal in properly labelled drums for disposal in an area approved by local authority by-laws. Wash excess with plenty of water.

7. HANDLING and STORAGE

Handling Advice: Keep containers closed at all times - check regularly for leaks or spills. Transport and store upright. Avoid eye contact and repeated or prolonged skin contact. Do not eat, drink or smoke in handling areas. Always remove contaminated clothing and wash hands before eating, drinking, smoking or using the toilet. Wash contaminated clothing and other protective equipment before storage or re-use.

Storage Advice: Classified as a Combustible Liquid for the purposes of storage and handling. Refer to the appropriate Regulations for storage and transport requirements.
Store in the original container, in a cool, dry, well-ventilated area out of sunlight and away from heat, strong oxidising agents and open flame. Do not combine part drums of the same product, as this may cause of contamination. Do not mix with other chemicals.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Standards:	No value assigned for this specific material by ASCC.
Ventilation:	Natural or local exhaust ventilation should be adequate under normal use conditions. Keep containers closed when not in use.
Personal Protection:	Protective equipment is recommended, including gloves, safety glasses and safety shoes. Observe good standards of hygiene and cleanliness. Trousers, long sleeved shirt and closed in safety footwear should be worn as a general precaution. If there is a risk of inhalation of vapour or spray mists, wear an organic vapour respirator meeting the requirements of AS1715 and AS1716.

9. PHYSICAL and CHEMICAL PROPERTIES

Appearance:	Clear green mobile liquid.
Odour:	Mild Eucalyptus odour
pH (Neat)	Not applicable.
S.G.:	1.0
Boiling Point (°C):	No data.
Solubility:	The product is fully soluble in water and solvents.
Flash Point (°C):	>67ºC (Closed Cup).

10. STABILITY and REACTIVITY

Stability:	No data.
Conditions To Avoid:	Do not combine part drums of the same product, as this may be a source of contamination.

Incompatible Materials: Incompatible with strong oxidising agents.
Hazardous Decomposition Products: Thermal decomposition may generate oxides of carbon.
Hazardous Reactions: None known.

11. TOXICOLOGICAL INFORMATION

No adverse health effects expected if the product is handled in accordance with this Material Safety Data Sheet and the product label. Symptoms and effects that may arise if the product is mishandled and over exposure occurs are:

ACUTE EFFECTS

Swallowed: May cause nausea, vomiting, headache, drowsiness and central nervous system depression
Eye: May cause irritation.
Skin: May cause irritation to skin with long and repeated contact.
Inhalation: Breathing in mist or aerosols may cause respiratory irritation.

12. ECOLOGICAL INFORMATION

Ecotoxicity Data: Avoid contaminating waterways.

13. DISPOSAL CONSIDERATIONS

Disposal: Avoid unauthorised discharge to sewer. The product is suitable for disposal by landfill through an approved agent.

14. TRANSPORT INFORMATION

AIR, SEA, ROAD AND RAIL TRANSPORT: Not Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Air, Road and Rail.
UN Number: None
UN Proper Shipping Name: None
Class & Subsidiary Risk: None
Hazchem Code: None
Packaging Group: None

15. REGULATORY INFORMATION

Poisons Schedule (AUST): None
Other: None.

16. OTHER INFORMATION

None.

This MSDS summarises to our best knowledge, at the date of issue, the chemical health and safety hazards of the material and general guidance on how to handle the material in the workplace. Since Choice Chem cannot anticipate or control the conditions under which the product may be used, each user must, prior to usage, assess and control the risks arising from its use of the material.
If clarification or further information is needed, the user should contact Choice Chem.
Choice Chem’s responsibility for the material as sold is subject to our standard terms and conditions, a copy of which is available on request.

DATE OF ISSUE: Tuesday 14 June. This MSDS replaces all other issues. PREPARED BY: Peter Spry

Executive Summary and Technical Report

Exhaust Gas Analysis – Mercedes ML63 AMG

By

Nicole SY Liau (MIChemE, CEng)

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EXECUTIVE SUMMARY

FCC is a fuel conditioner produced by ADDFUEL PTY LTD which is a blend of surfactants (detergents), oxygenates and corrosion inhibitors (refer MSDS in Attachment 3) developed to improve fuel efficiency and saving the maintenance costs through cleaner and better combustion process. It's a non-hydrocarbon fuel conditioner that may clean fuel and improves performance whilst lowering pollutants emission to the environment.

During recent exhaust gas analysis carried out on the Mercedes ML63 AMG model, the result shows reduction in both carbon monoxide (CO) and oxide of nitrogen (NOx) emissions. Particularly in NOx as high as 75% reduction has been observed during vehicle ramp up condition.

Carbon monoxide is a toxic, colourless and odourless gas. It affects healthy and unhealthy people. Increased levels of carbon monoxide reduce the amount of oxygen carried by haemoglobin around the body in red blood cells. The result is that vital organs, such as the brain, nervous tissues and the heart, do not receive enough oxygen to work properly. No more than 2.5% of haemoglobin can be bound to carbon monoxide before some health effects become noticeable. At very high concentrations of carbon monoxide, up to 40% of the haemoglobin can be bound to carbon monoxide in this way. This level will almost certainly kill humans.

On the other hand, NOx is produced from the reaction of nitrogen and oxygen gases during combustion especially at higher temperatures. NOx mainly impacts on respiratory conditions causing inflammation of the airways at high levels. Long term exposure can decrease lung function, increase risk of respiratory conditions and increases the response to allergens. NOx also contribute to the formation of fine particles (PM) and ground level ozone, both of which are associated with adverse health effects.

CO and NOx are the by-products caused by incomplete combustion where air intake is limited. The relative amount of CO and NOx produced depends on the efficiency of combustion. FCC has the effect of improving the combustion process which notably reduces CO and NOx emissions.

As the Australia Government has taken steps to manage and reduce the amount of CO and NOx emissions to the environment including implementation of tighter vehicle emission standard, hence using FCC fuel additive could be considered beneficial to achieve cleaner burning of the vehicle's engine.

TECHNICAL REPORT FOR MERCEDES ML63 AMG EXHAUST GAS ANALYSIS

On 18 November 2016, exhaust gas analysis was carried on Mercedes ML63 AMG model to investigate the benefit of using FCC particularly to the improvement of reducing vehicle emissions. The car was powered by petrol and the FCC was added on 3000:1 ratio. Tests were run on minimum and maximum rated power i.e.: 600 rpm and 3,000 rpm respectively. The maximum idling speed was fixed at 3,000 rpm as the average cruising speed despite of the model design maximum torque could goes higher.

The undiluted exhaust gas limit is set at 1,500 ppm CO and 1,000 NOx. The exhaust gas was diluted in a control volume before the emissions concentration was recorded. The test results of the vehicle emissions before and after the FCC fuel additive was added were recorded in Attachment 1 and 2 respectively.

Carbon Monoxide (CO) Emission

The emission of carbon monoxide (CO) before and after the FCC was added had been investigated and recorded. The CO emission trends are presented graphically in Figure 1, extracted from results obtained from the lab test reports in Attachment 1 and 2.

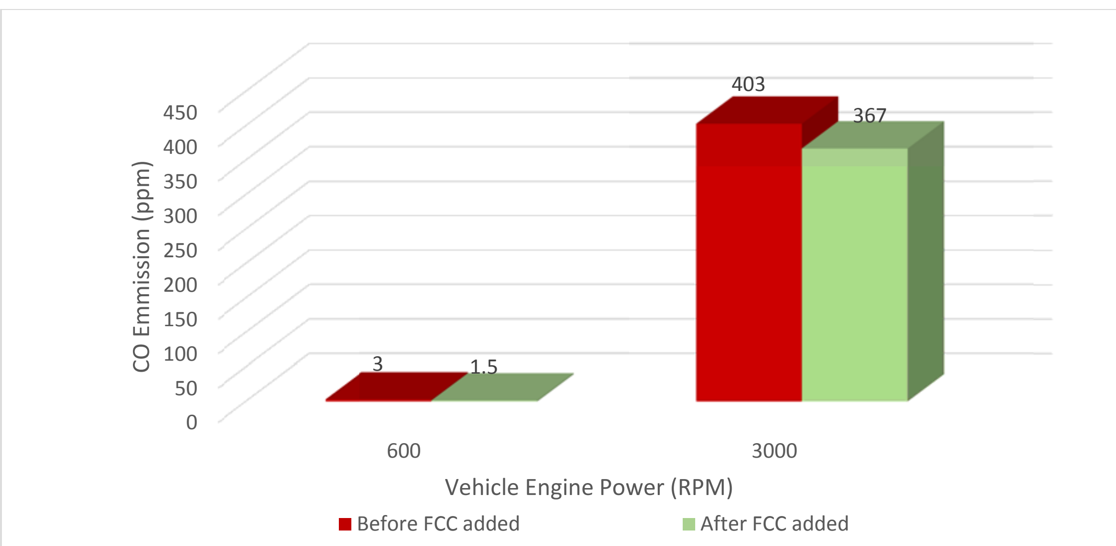

Figure 1: Mercedes ML63 AMG Model - CO Emission Before and After FCC was added

Figure 1 shows the CO emission in the exhaust gas before and after the FCC additive, measure in part per million, during both minimum and maximum engine speeds

At the beginning, when the engine was running at minimum idling speed of 600 rpm, the CO emission was reduced to nearly 50% after the FCC was added. Whereas, approximately 9% CO reduction was observed when the vehicle was ramp up to the maximum idling speed of 3,000 ppm. Both results have demonstrated the effectiveness of using FCC additive in minimising the CO emission from the exhaust gas.

The oxygenated chemical compound i.e.: alkoxy propanols (refer MSDS in Attachment 3) within the FCC contains oxygen as a part of their chemical structure. The exhaust emissions such as CO and HC level were progressively reduced as oxygen content is increased.

It is recommended that higher ratio of FCC additive to be considered during engine ramp up in attempting to achieve further reduction in CO emission.

Oxide of Nitrogen (NOx) Emission

It is noticed from the lab test results (Attachment 1 and 2) that no NOx emission was detected during minimum idling speed of 600 rpm. In general, the petrol engine ignites the fuel-air mixture with a spark, therefore compression ratio and temperature are relatively lower than that of diesel engine. NOx is formed when nitrogen and oxygen are combined under high temperature and pressure. As the premixed fuel-air mixture allows more complete combustion within the petrol engine, therefore excessive oxygen content is not expected at the exhaust particularly during low engine speed. Thus the formation of NOx may not present in the current Mercedes car model even without the FCC additive.

For this reason, the discussion of NOx emission will only focus on the results observed during the engine maximum rated speed of 3,000 rpm.

The graphical summary of the NOx emission is presented in Figure 2 below.

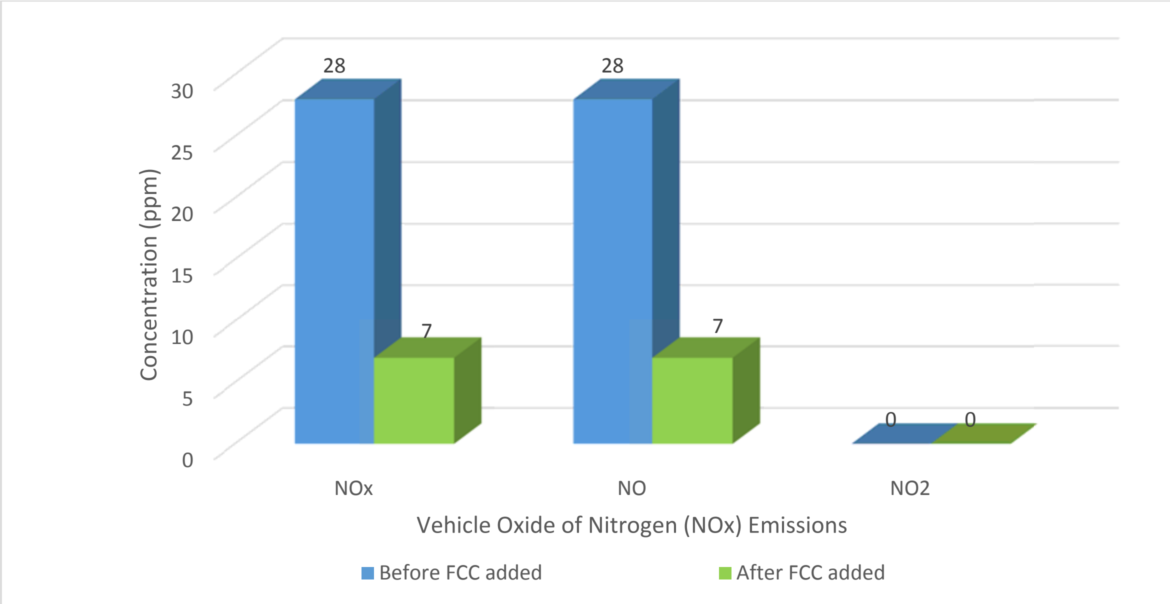

Figure 2: Mercedes ML63 AMG Model - NOx Emission Before and After FCC was added during Maximum Rate Power of 3,000 rpm

Figure 2 compares NOx emission before and after FCC additive was added during maximum rate power of 3,000 rpm, in part per million. The result has shown that the NOx emissions have been significantly lessened with the FCC additive i.e.: about 75% reduction has been recorded. NOx is produced during the combustion process when nitrogen and oxygen are present at elevated temperatures. At high temperatures, they undergo an endothermic reaction producing various oxides of nitrogen. Such temperatures can arise inside an internal combustion engine within the vehicle. The two elements combine to form nitric oxide (NO) and nitrogen dioxide (NO_2). It is also noticed that the Mercedes ML63 AMG model engine does not produce NO_2 regardless of FCC addition. NOx is harmful to environment as it combines with other pollutants in the atmosphere and creates O_3, a substance known as ground level ozone.

Overall, both results in Figure 1 and Figure 2 have demonstrated that using FCC additive in petrol engine will reduce the emission of carbon monoxide (CO) and oxide of nitrogen (NOx). Particularly in NOx emission, considerable amount of reduction has been seen. Both CO and NOx are harmful substances to the environment and are associated with adverse health effects. Therefore the use of FCC additive could be worthwhile in the effort of minimising pollution to the environment.

ATTACHMENT 1 – EXHAUST GAS ANALYSIS BEFORE FUEL ADDITIVE

CERTIFICATE OF EXHAUST GAS ANALYSIS

SERIAL No. WDC1660742A400786

MINING COMPANY: N/A (emissions test before fuel additive) *TEST DATE: 16/11/2016*
UNIT OWNER: SIAM Group *EXPIRY DATE: 16/11/2017*

SITE CONTRACTOR OPERATING UNIT: N/A (emissions test before fuel additive)
NAME OF MINE/DECLINE: N/A (emissions test before fuel additive)
CONTACT PERSON: Stuart Martin (ADDFUEL)
PHONE: 0488 678 046 *FAX: TBA*

UNIT MAKE: Mercedes *REGO No.: 1EXI 908*
MODEL No: ML63 AMG *ASSET No.: N/A*
ENGINE MAKE: Mercedes *ENGINE No.: WDC1660742A400786*
ENGINE CAPACITY: 5.5 litres *ENGINE kW: 386kW*
TOTAL HOURS/KM RUN: 20,932kms *ORIGINAL ENGINE: Yes (AMG tuned)*

EXHAUST TREATMENT TYPE: Bi-Turbo (AMG) *BANK: V8 (PETROL)*

ANALYSIS RESULTS

UNDILUTED EXHAUST GAS – Maximum level of exhaust gases permitted ; 1000ppm NOx 1500 ppm CO

ALTITUDE m	Rpm	TEMP °C	O2%	CO2%	Effg%	Effn%	CO ppm	NOx ppm	NO ppm	NO^2 ppm
Min Rated Power (idle)	600	34					3	0	0	0
Max Rated Power No Load (High idle)	3000	90					403	28	28	0
Max Rated Power Load Condition										

OPACITY TEST DATA

Opacity Meter calibrated before use (yes/no)? - N/A
Average peak opacity registered at snap idle - N/A % Maximum Opacity 50%
Average base opacity at idle - N/A %
Speed of engine during snap idle test, if available? - N/A rpm
Was opacity reading & procedure used representative? - N/A
Location of test, Surface or Underground? - Surface

EVALUATOR's NAME: S. Niederberger ***SIGNATURE:***

COMMENTS: PETROL / NOT FOR UNDERGROUND MINE USE ***DATE: 16/11/2016***

Notes: Effn% = overall efficiency of combustion system Effg% = efficiency of gases existing the exhaust related by ratios of CO2 to CO and O2 in the exhaust gases.

<u>ATTACHMENT 2 – EXHAUST GAS ANALYSIS AFTER FUEL ADDITIVE</u>

CERTIFICATE OF EXHAUST GAS ANALYSIS

SERIAL No. WDC1660742A400786

MINING COMPANY: N/A (emissions test after fuel additive) *TEST DATE: 18/11/2016*
UNIT OWNER: SIAM Group *EXPIRY DATE: 18/11/2017*

SITE CONTRACTOR OPERATING UNIT: N/A (emissions test after fuel additive)
NAME OF MINE/DECLINE: N/A (emissions test after fuel additive)
CONTACT PERSON: Stuart Martin (ADDFUEL)
PHONE: 0488 678 046 *FAX: TBA*

UNIT MAKE: Mercedes *REGO No.: 1EXI 908*
MODEL No: ML63 AMG *ASSET No.: N/A*
ENGINE MAKE: Mercedes *ENGINE No.: WDC1660742A400786*
ENGINE CAPACITY: 5.5 litres *ENGINE kW: 386kW*
TOTAL HOURS/KM RUN: 21,318kms *ORIGINAL ENGINE: Yes (AMG tuned)*

EXHAUST TREATMENT TYPE: Bi-Turbo (AMG) *BANK: V8 (PETROL)*

ANALYSIS RESULTS

UNDILUTED EXHAUST GAS – Maximum level of exhaust gases permitted ; 1000ppm NOx 1500 ppm CO

ALTITUDE m	Rpm	TEMP °C	O2%	CO2%	Effg%	Effn%	CO ppm	NOx ppm	NO ppm	NO^2 ppm
Min Rated Power (idle)	600	36					1.5	0	0	0
Max Rated Power No Load (High idle)	3000	115					367	7	7	0
Max Rated Power Load Condition										

OPACITY TEST DATA

Opacity Meter calibrated before use (yes/no)?	-	*N/A*	
Average peak opacity registered at snap idle	-	*N/A*	*% Maximum Opacity 50%*
Average base opacity at idle	-	*N/A*	*%*
Speed of engine during snap idle test, if available?	-	*N/A*	*rpm*
Was opacity reading & procedure used representative?	-	*N/A*	
Location of test, Surface or Underground?	-	*Surface*	

EVALUATOR's NAME: S. Niederberger ***SIGNATURE:*** S Niederberger

COMMENTS: PETROL / NOT FOR UNDERGROUND MINE USE ***DATE: 18/11/2016***

Notes: Effn% = overall efficiency of combustion system Effg% = efficiency of gases existing the exhaust related by ratios of CO2 to CO and O2 in the exhaust gases.

ATTACHMENT 3 – FCC MSDS

Material Safety Data Sheet

1. IDENTIFICATION of MATERIAL and SUPPLIER

Product Name:	**FUEL CONDITIONER CONCENTRATE**
Other Names:	FCC, Fuels Gold & Fuel Set EU
Recommended Use:	Fuel additive for petrol and Diesel fuels
Supplier:	**GND Holdings Pty Ltd trading as Choice Chem**
ABN:	**16 122 257 176**
Address:	**27 Boulder Road,** **Malaga Western Australia 6090**
Telephone:	**(618) 9248 9590**
Facsimile:	**(618) 9249 4810**
Emergency Telephone:	**+61 400 015 083**

2. HAZARDS IDENTIFICATION

Hazard Classification: This material is not considered **hazardous** according to the criteria of ASCC. However prolonged skin or eye contact can cause irritations.

Hazard Category: **N/A**

Risk Phrases: N/A

Safety Phrases: N/A

3. COMPOSITION/INFORMATION on INGREDIENTS

Chemical Name	CAS No	Proportion (%w/w)
Non Ionic surfactants (not considered hazardous)	N/A	30-60%
Alkoxy propanols		30-60%
Dye	Proprietary	<10%
Fragrance	Proprietary	<10%

4. FIRST AID MEASURES

FIRST AID

Swallowed: If swallowed, do NOT induce vomiting. Give a glass of water. Seek medical advice. For advice, contact a Poisons Information Centre (Phone Australia 131126) or a doctor.

Eye: If in eyes, hold eyelids apart and flush the eye continuously with running water. Continue flushing until advised to stop by the Poisons Information Centre or a doctor, or for at least 15 minutes.

Skin: If skin or hair contact occurs, remove contaminated clothing and flush skin and hair thoroughly with running water. Continue flushing until advised to stop by the Poisons Information Centre or a doctor.

Inhaled: Remove the victim from the source of exposure to fresh air. Avoid becoming a casualty. Seek medical advice if effects persist.

ADVICE TO DOCTOR Treat symptomatically.

5. FIRE FIGHTING MEASURES

Suitable Extinguishing Media: Water spray, foam, carbon dioxide or dry chemical powder.
Fire / Explosion Hazard: The product is a combustible liquid. Thermal decomposition may generate oxides of carbon.
Precautions for fire fighters and special protection equipment: Fire Fighters should wear self-contained breathing apparatus to minimise the risk of exposure to the fumes.
Hazchem Code: None

6. ACCIDENTAL RELEASE MEASURES

Spills: Spills are slippery. Ensure adequate ventilation. Avoid accidents, clean up immediately. Wear protective equipment to prevent skin and eye contamination. Contain the spill and prevent contamination into drains and waterways. Absorb with sand or other similar material. Collect and seal in properly labelled drums for disposal in an area approved by local authority by-laws. Wash excess with plenty of water.

7. HANDLING and STORAGE

Handling Advice: Keep containers closed at all times - check regularly for leaks or spills. Transport and store upright. Avoid eye contact and repeated or prolonged skin contact. Do not eat, drink or smoke in handling areas. Always remove contaminated clothing and wash hands before eating, drinking, smoking or using the toilet. Wash contaminated clothing and other protective equipment before storage or re-use.
Storage Advice: Classified as a Combustible Liquid for the purposes of storage and handling. Refer to the appropriate Regulations for storage and transport requirements.
Store in the original container, in a cool, dry, well-ventilated area out of sunlight and away from heat, strong oxidising agents and open flame. Do not combine part drums of the same product, as this may cause of contamination. Do not mix with other chemicals.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Standards: No value assigned for this specific material by ASCC.
Ventilation: Natural or local exhaust ventilation should be adequate under normal use conditions.
Keep containers closed when not in use.
Personal Protection: Protective equipment is recommended, including gloves, safety glasses and safety shoes. Observe good standards of hygiene and cleanliness. Trousers, long sleeved shirt and closed in safety footwear should be worn as a general precaution. If there is a risk of inhalation of vapour or spray mists, wear an organic vapour respirator meeting the requirements of AS1715 and AS1716.

9. PHYSICAL and CHEMICAL PROPERTIES

Appearance:	Clear green mobile liquid.
Odour:	Mild Eucalyptus odour
pH (Neat)	Not applicable.
S.G.:	1.0
Boiling Point (°C):	No data.
Solubility:	The product is fully soluble in water and solvents.
Flash Point (°C):	>67ºC (Closed Cup).

10. STABILITY and REACTIVITY

Stability: No data.
Conditions To Avoid: Do not combine part drums of the same product, as this may be a source of contamination.

Incompatible Materials: Incompatible with strong oxidising agents.
Hazardous Decomposition Products: Thermal decomposition may generate oxides of carbon.
Hazardous Reactions: None known.

11. TOXICOLOGICAL INFORMATION

No adverse health effects expected if the product is handled in accordance with this Material Safety Data Sheet and the product label. Symptoms and effects that may arise if the product is mishandled and over exposure occurs are:

ACUTE EFFECTS

Swallowed: May cause nausea, vomiting, headache, drowsiness and central nervous system depression
Eye: May cause irritation.
Skin: May cause irritation to skin with long and repeated contact.
Inhalation: Breathing in mist or aerosols may cause respiratory irritation.

12. ECOLOGICAL INFORMATION

Ecotoxicity Data: Avoid contaminating waterways.

13. DISPOSAL CONSIDERATIONS

Disposal: Avoid unauthorised discharge to sewer. The product is suitable for disposal by landfill through an approved agent.

14. TRANSPORT INFORMATION

AIR, SEA, ROAD AND RAIL TRANSPORT: Not Classified as Dangerous Goods by the criteria of the Australian Dangerous Goods Code (ADG Code) for transport by Air, Road and Rail.
UN Number: None
UN Proper Shipping Name: None
Class & Subsidiary Risk: None
Hazchem Code: None
Packaging Group: None

15. REGULATORY INFORMATION

Poisons Schedule (AUST): None
Other: None.

16. OTHER INFORMATION

None.

This MSDS summarises to our best knowledge, at the date of issue, the chemical health and safety hazards of the material and general guidance on how to handle the material in the workplace. Since Choice Chem cannot anticipate or control the conditions under which the product may be used, each user must, prior to usage, assess and control the risks arising from its use of the material.
If clarification or further information is needed, the user should contact Choice Chem.
Choice Chem's responsibility for the material as sold is subject to our standard terms and conditions, a copy of which is available on request.

DATE OF ISSUE: Tuesday 14 June. This MSDS replaces all other issues. PREPARED BY: Peter Spry

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7. ISO CERTIFICATE

CERTIFICATE OF REGISTRATION

This is to certify that:

G N D Holdings Pty Ltd

ABN 16 122 257 176

Trading As

Choice Chem

27 Boulder Road Malaga WA 6015 AUSTRALIA

operates a

QUALITY MANAGEMENT SYSTEM

which complies with the requirements of

ISO 9001:2015

for the following scope

The supply and production of a range of chemicals.

Certificate No: QEC24977

Issued: 14 March 2017
Expires: 10 June 2020

Originally Certified: 10 June 2008
Current Certification: 9 March 2017

Nicole Grantham
General Manager SAI Global Certification Services

Certified System ISO 9001

JAS-ANZ WWW.JAS-ANZ.ORG/REGISTER

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8. MATERIAL SAFETY DATA SHEET

Material Safety Data Sheet

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Hazard Category: **N/A**

Risk Phrases: N/A

Safety Phrases: N/A

3. COMPOSITION/INFORMATION on INGREDIENTS

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Fire / Explosion Hazard: The product is a combustible liquid. Thermal decomposition may generate oxides of carbon.
Precautions for fire fighters and special protection equipment: Fire Fighters should wear self-contained breathing apparatus to minimise the risk of exposure to the fumes.
Hazchem Code: None

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8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Exposure Standards: No value assigned for this specific material by ASCC.
Ventilation: Natural or local exhaust ventilation should be adequate under normal use conditions. Keep containers closed when not in use.
Personal Protection: Protective equipment is recommended, including gloves, safety glasses and safety shoes. Observe good standards of hygiene and cleanliness. Trousers, long sleeved shirt and closed in safety footwear should be worn as a general precaution. If there is a risk of inhalation of vapour or spray mists, wear an organic vapour respirator meeting the requirements of AS1715 and AS1716.

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S.G.:	1.0
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Solubility:	The product is fully soluble in water and solvents.
Flash Point (°C):	>67ºC (Closed Cup).

10. STABILITY and REACTIVITY

Stability: No data.
Conditions To Avoid: Do not combine part drums of the same product, as this may be a source of contamination.

Incompatible Materials: Incompatible with strong oxidising agents.
Hazardous Decomposition Products: Thermal decomposition may generate oxides of carbon.
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9. FAQs

FAQs: FCC FUEL CONDITIONER

Will FCC Fuel Conditioner void my engine warranty?

No. Under Australian & International laws, for a manufacturer to void a warranty they must prove that FCC Fuel Conditioner caused the damage. In the 20+ years this formulation has been sold, throughout over 40 countries, there has never been a claim of damage caused.

Will FCC Fuel Conditioner harm my O2 sensors, or my Catalytic Converters?

No. FCC Fuel Conditioner will not harm any metallic components or engine components.

Which fuels are compatible with FCC Fuel Conditioner concentrate?

- D2 Diesel (Distillate)
- Petrol (including 2 stroke)
- Kerosene
- Fuel Oil
- Any liquid hydrocarbon fuel

How does FCC Fuel Conditioner effect my exhaust emissions?

This question deserves a 2-part answer, and highlights the brilliance behind this product's remarkable efficiency. Firstly, FCC Fuel Conditioner enables your Injectors or carburettor to deliver a finer atomisation of fuel at every pulse, allowing a greater surface area of fuel for each combustion stroke. Secondly, during each combustion event, FCC Fuel Conditioner slows & prolongs the actual fuel burning process. Therefore, when using FCC Fuel Conditioner treated fuel, from each combustion cycle you'll get the following results:

- Less CO produced. (Carbon monoxide)
- Less unburnt Hydrocarbons. (HC)
- Less particulates. (Less smoke)

How should I apply FCC Fuel Conditioner to my fuel?

The ideal place to admit FCC Fuel Conditioner is directly to your fuel tank before filling. If you have a Bulk Storage Tank, FCC Fuel Conditioner should be added prior to fuel delivery to enable complete dispersion, & the relevant sedimentary impurities to be dissolved.

What is the Dosage Rate?

Normally 1 litre of FCC Fuel Conditioner treats 4,000 litres of fuel. (1:4,000) However, if your fuel is heavily contaminated, the initial dosage rate can be increased.

Can I overdose my fuel with Fuel Conditioner (FCC)?

Yes. When dosed at excessive levels FCC will separate and money may be wasted (1:100 as opposed to recommended 1:4000)

What happens to any water that was in my fuel?

All water is dissolved into the FCC Fuel Conditioner concentrate, which in turn is absorbed into your fuel. During this process, the prior water particles are reduced in size down to around one micron in size, thereby significantly reducing mechanical wear in Diesel Injectors.

Does FCC Fuel Conditioner react with Tetraethyl Lead in fuel?

No

Does FCC Fuel Conditioner react with Sulphur in fuel?

No. FCC Fuel Conditioner prevents Sulphur becoming acids within your fuel system, because the water vapour required to form acid is completely absorbed into the fuel, thereby breaking the formation cycle.

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EPA NO: 264220001

ADDFUEL

FAQs

How can I tell if my fuel system is affected by moisture &/or "Fuel Bug"?

Check for the following evidence:

- "Rotten Egg" odour, generated by Sulphur
- Fuel colour being darker than normal
- Evidence of biomass/fungal sludge, within tanks &/or filters
- Corrosion in tanks/fuel lines, etc

Once I begin to use FCC Fuel Conditioner, what happens to the "Fuel Bug"?

FCC Fuel Conditioner will absorb & disperse all water molecules within your fuel. This destroys the environment for the "Fuel Bug" (Cladisporium Resinae) to survive. With light infestations of "Fuel Bug", the remaining biomass will be dissolved into the fuel & burned in the normal combustion process. In heavy infestations some quantities of biomass will be transported into the fuel filters. It will be necessary to monitor filters closely in the early stages of treating a major event.

Once I've solved my "Fuel Bug" problems, should I continue to use FCC Fuel Conditioner concentrate?

Yes. Condensation of air-borne moisture will re-occur, as it does in every fuel tank that has an airspace. Continual use of FCC Fuel Conditioner will provide financial gains well in excess of the cost.

At what fuel temperature will FCC Fuel Conditioner become ineffective?

None

What preparations are required before the use of FCC Fuel Conditioner?

None. However, where heavy contamination & water are present, it is wise to syphon off contaminants as much as possible prior to adding FCC Fuel Conditioner.

Can FCC Fuel Conditioner be used in the fuel storage tanks for Standby Generators?

Yes, but some form of agitation (such as adding more fuel) is encouraged to enable the complete effectiveness of the product.

Does FCC Fuel Conditioner help to overcome fuel storage problems, and "Stale" fuel?

Yes. It will solve condensation related problems, and stop storage tanks & fittings from rusting & corrosion that is caused by fuel-based moisture. In most instances FCC Fuel Conditioner will overcome the problems that come from fuel ageing.

Does FCC Fuel Conditioner affect Vanadium levels in fuel?

No.

What effect will FCC Fuel Conditioner have toward "Salt Water" contamination in fuels?

FCC Fuel Conditioner will dissolve and remove the water molecules. Generally, the remaining salt will settle out and eventually accumulate in the fuel filters.

Does FCC Fuel Conditioner have any effect on either the Cetane or Octane ratings of fuel?

No. Neither the Cetane or Octane ratings are affected by the addition of FCC Fuel Conditioner.

CONTACT:

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0404 885 210
colin@addfuel.com.au

Stuart Martin
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stuart@addfuel.com.au

FCC FUEL CONDITIONER

EPA Registered
EPA NO: 264220001

ADDFUEL

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10. CONTACTS

CONTACTS

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