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Retrofitting Urban Buses to Reduce PM and NO_2

P. Richards and B. Terry
Associated Octel Company

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ABSTRACT

In an attempt to improve ambient air quality, retrofit programmes have been encouraged; targeting reductions in PM emissions by means of diesel particulate filters (DPFs). However depending on the DPF design and operating conditions increased nitrogen dioxide (NO_2) emissions have been observed, which is causing concern. Previous work showed that retrofitting a DPF system employing a fuel borne catalyst (FBC) to facilitate regeneration, reduced NO_2 emissions. This paper outlines the investigation of a base metal coated DPF to enhance the reduction of NO_2. Such a DPF system has been fitted to older technology buses and has demonstrated reliable field performance.

INTRODUCTION

New vehicles entering the market meet existing emissions standards; due to fiscal incentives some vehicles also meet the lower emissions limits of future standards. Some diesel passenger cars are now fitted with diesel particulate filters (DPFs) and thus produce particulate matter (PM) emissions well below prescribed limits (1). However due to the replacement rate of the vehicle fleet, there is a delay before the full benefit of these cleaner vehicles can be fully realised. To accelerate the improvements in air quality, retrospective legislation is being considered in many areas. In city centres such as London, public transport has been identified as a major contributor to air pollution (2) particularly in respect of PM and oxides of nitrogen (NO_X). As a result retrofit schemes have been put in place (3), often with fiscal incentives, aimed at reducing these emissions (4). To date the main focus has been on reducing the PM emissions by means of diesel particulate filter (DPF) systems, but with some attempt to reduce both PM and NO_X by means of re-engining (replacing a pre-Euro engine with a Euro II engine). Many of the DPF systems rely on platinum (Pt) based catalyst to aid the regeneration of the DPF in some way. The Pt catalyst will convert some of the nitric oxide (NO) within the NO_X, into nitrogen dioxide (NO_2). The NO_2 will be reduced back to NO whilst oxidising the trapped soot within the DPF. However depending on the DPF design and the operating conditions some of this NO_2 may be emitted into the atmosphere. Increased NO_2 emissions are now becoming an area of interest.

For this reason a DPF system that does not increase NO_2 emissions has a potential benefit. If a system can be designed that not only significantly reduces PM emissions but also significantly reduces NO_2 emissions then the attractiveness of the system is enhanced. Previous work has shown that retrofitting a DPF system that employs a fuel borne catalyst (FBC) to facilitate the regeneration of the DPF, produced significant reductions in NO_2 emissions (5). Unlike some other DPF systems the FBC system does not rely on the NO_2 to oxidise the trapped soot. This paper presents results from an investigation into the application of a proprietary base metal coating to a DPF to enhance the reduction of NO_2. Such a DPF system has been fitted to older technology buses and results are presented demonstrating reliable field performance and the effect on exhaust emissions.

SYSTEM PERFORMANCE

An earlier programme of work had been undertaken to demonstrate that the use of a bare (non-catalysed) DPF relying upon an FBC for regeneration, was a reliable option for retrofitting London BlackCabs (6). This work demonstrated that such a system not only effectively reduced the PM emissions from these vehicles but it also showed reductions in NO_2 emissions (5). It was suggested that the decrease in NO_2 emissions was as a result of the NO_2 being reduced as it oxidised the trapped soot within the DPF. However by using a bare filter there was no significant reduction of either hydrocarbon (HC) or carbon monoxide (CO) emissions. The use of a conventional diesel oxidation catalyst (DOC) would effectively reduce the HC and CO emissions, but a Pt based DOC has been shown to have a variable effect on NO_2 emissions (7). It was therefore proposed that a base metal catalyst be used to promote the oxidation of HC and CO without promoting the oxidation of NO to NO_2. To simplify the system the base metal catalyst was applied as a coating to the DPF. A Liqtech silicon carbide (SiC) DPF was chosen for the substrate. The performance of the system would be assessed both in terms of the effect of the catalysed filter on the emissions characteristics of a vehicle and on the ability of the combination of the catalysed DPF and the FBC to ensure reliable regeneration of the DPF in active service. Previous work had shown that a catalytically coated DPF would not operate satisfactorily in low duty applications without the use of the FBC (8). The class of vehicle selected for this work was a single deck bus and a double deck bus. The results from these two types of vehicle are discussed in the following sections.

SINGLE DECK BUS

Outside of Greater London, probably the most common form of public transport vehicle is the single deck bus. Due to the replacement cost of such vehicles the life expectancy of these vehicles is typically 15 years. A 1994 Dennis Dart bus was chosen as representative of this class of vehicle and is shown in Figure 1. The bus was operated by Warrington Borough Transport in the North West of England.

Figure 1. Dennis Dart, single deck bus

The bus was fitted with a Cummins "B" series engine, details of which are given in Table 1. This type of engine and its derivatives is one of the most common in this class.

Table 1. Single deck bus engine details

Type	Cummins 6BTA-130
Cylinder arrangement	6 In-line
Bore	102 mm
Stroke	120 mm
Capacity	5883 cm^3
Compression ratio	17.6 : 1
Peak Power	97 kW @ 2500 rev/min
Peak Torque	470 Nm @ 1500 rev/min
Emissions specification	Euro I

To demonstrate the effect of the catalysed DPF on the tail-pipe emissions of the bus, emissions testing was performed at an independent test laboratory. The bus was tested with the conventional exhaust system and again with a system containing a 19.1 cm x 20.3 cm (7.5" x 8") catalytically coated SiC wall flow DPF, giving 5.8 ltrs of DPF volume. This was considered to be the smallest acceptable filter volume for the 5.9 ltrs of pressure charged engine volume. From an emissions reduction stand point this was considered to be the worst case scenario. The bus was driven to the FIGE (Forschungsinstitut Gerausche und Erschutterungen) test cycle. The regulated emissions were determined from bag analysis using Horiba NDIR analysers for CO and CO_2 with a heated FID for the total HC and a chemiluminescent analyser for the NO_X. In addition the major NO_X species, i.e. NO, NO_2 and N_2O were measured on a second by second basis using a Nicolet Fourier Transform InfraRed (FTIR) analyser.

The regulated emissions measurements demonstrated the benefits of the base metal catalyst for reducing the HC and CO emissions whilst the DPF substrate ensured a high level of PM reduction. The emissions of HC were reduced by 94% whilst the CO emissions were reduced by 78%. Although such old technology engines would be expected to have a high volatile fraction of PM leading to reduced filtration efficiency in terms of mass, the presence of the catalytic coating resulted in a PM mass reduction of 87%. This resulted in an overall cycle PM emission equivalent to 0.145 g/kWh, i.e. 91% of the Euro III limit of 0.16 g/kWh. The regulated emissions results are given in Appendix 1.

The regulated NO_X emissions results showed a reduction of 11%. The NO_X reduction determined from the FTIR testing was not as great as from the bag analysis, but it must be remembered that there are no corrections applied to the FTIR data to allow for ambient conditions, variations in distance driven, etc. Figure 2 shows the total NO_X data from the FTIR, for the OE exhaust system and the DPF system along with the vehicle speed trace for the complete FIGE cycle.

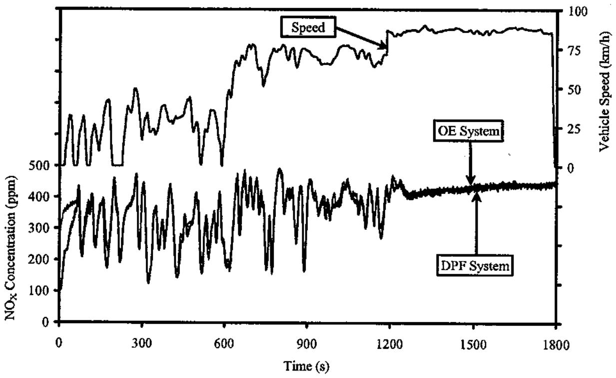

Figure 2. NO_X emissions for single deck bus

As can be seen from the chart the NO_X trace for the OE and the DPF systems lie on top of one another except during the first minute or so of the cycle. As the FIGE cycle is a hot start test procedure there is a high probability that there will be differences in the temperatures of various components at the start of the test and this difference in NO_X emissions, during the first minute has been attributed to test to test variation. It is also clear from Figure 2 that there is a strong correlation between the NO_X emissions and the engine duty, i.e. during the accelerations or sustained high duty operation the NO_X emissions are high and during decelerations the NO_X emissions are low. There is however an underlying trend for the NO_X emissions to rise slightly throughout the cycle.

The corresponding traces for the NO_2 emissions are shown in Figure 3. It is immediately obvious from this figure that the base metal catalysed DPF has dramatically reduced the NO_2 emissions. The NO_2 emissions level is fairly constant throughout the cycle when the catalysed DPF is fitted. Without the DPF the NO_2 emissions tend to rise with the engine duty during the urban phase of the FIGE cycle. However unlike the total NO_X the emissions of NO_2 then tend to fall as the average engine operating temperature increases.

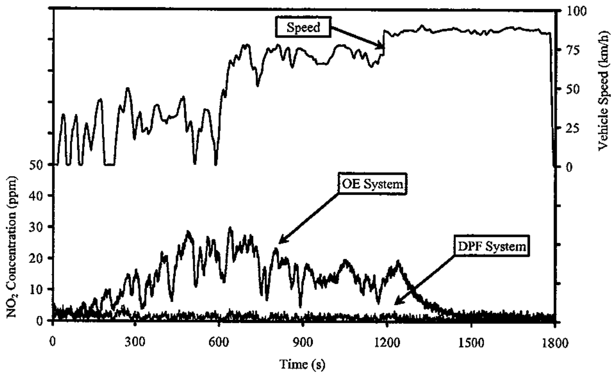

Figure 3. NO_2 emissions for single deck bus

Whilst the emissions testing had demonstrated the PM and NO_2 reduction potential of the system, for it to be a viable proposition it had to be shown that such a system would regenerate reliably in normal service conditions. For the in-service testing the bus was fitted with a 22.9 cm x 25.4 cm (9" x 10") SiC wall flow DPF, giving 10.4 ltrs of DPF volume. This is considered the appropriate size of DPF for the 5.9 ltrs of pressure charged engine volume. The DPF was fitted in place of the conventional silencer unit and was designed to provide noise attenuation at least equal to that of the existing silencer. Drive-by noise measurements conducted at an independent test laboratory confirmed this. The results of the drive-by noise measurements are given in Table 2.

Table 2. Drive-by noise measurements on single deck bus

OE system		DPF system	
Left side	Right side	Left side	Right side
79.6 dB(A)	80.5 dB(A)	78.3 dB(A)	79.6 dB(A)
80.1 dB(A)	80.9 dB(A)	78.6 dB(A)	79.9 dB(A)
80.3 dB(A)	80.8 dB(A)	78.7 dB(A)	79.7 dB(A)
80.7 dB(A)	80.9 dB(A)	79.3 dB(A)	79.4 dB(A)

To facilitate regeneration of the DPF a commercial FBC was used which was added to the fuel using a patented (9) on board dosing system. The bus equipped with the DPF was then put back into normal service in the Borough of Warrington. In order to monitor the system performance the DPF unit was equipped with thermocouples and a pressure transducer that were connected to a Grant 1000 series Squirrel data logger. The data logger was set to record data every 5 seconds while the bus was operating. From the logged data a pre-DPF temperature distribution was constructed. This is shown in Figure 4 as the percentage of time spent in each 10°C temperature window. As can be seen from the figure the temperature distribution approximates to a skewed normal distribution but with a secondary peak at 90°C to 100°C. This is indicative of the time spent at idle.

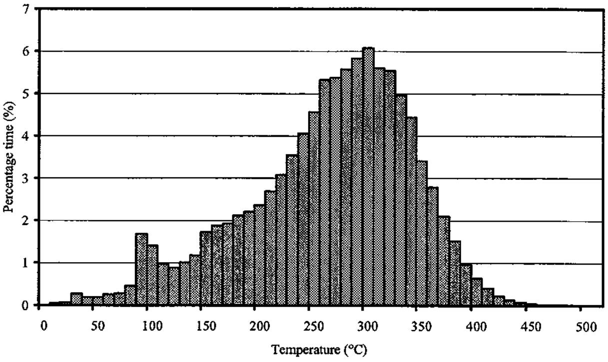

Figure 4. Temperature distribution for single deck bus

A temperature distribution as shown in Figure 4 appears favourable for reliable regeneration of an FBC based system. At low temperatures soot will accumulate in the DPF, but this soot will be laced with catalyst from the FBC and thus when favourable regenerating conditions are reached all of the trapped soot will tend to oxidise within a short space of time. Only 34.4% of the time was spent with a pre-DPF temperature below 250°C and for 12.4% of the time the pre-DPF temperature was above 350°C. There was also 1.5% of the time when the pre-DPF temperature exceeded 400°C. With this favourable temperature characteristic the DPF regenerated at an interval of approximately 3 days, which corresponded to a distance of approximately 1150 km. Based on the emissions test results for PM of 0.079 g/km, this equates to approximately 91 g of soot, or 8.7 g/ltr of DPF volume.

The pre-DPF and post-DPF temperatures during a typical regeneration are plotted in Figure 5. Although peak pre-DPF temperatures are quite high and at one point exceeds 400°C, the regeneration appears to have been initiated during a deceleration as opposed to at the peak of the acceleration where the temperature would be higher. However what has probably happened is that the regeneration has been initiated by the higher temperature but the rate of reaction, and hence the heat liberated, has increased due to the increased level of oxygen during the deceleration.

The fall in exhaust back pressure associated with this event indicated that the regeneration was complete within a minute, however due to the thermal inertia of the DPF the post-DPF temperature exhibits an exothermic "spike" for approximately 5 minutes with a peak temperature of 577.5°C.

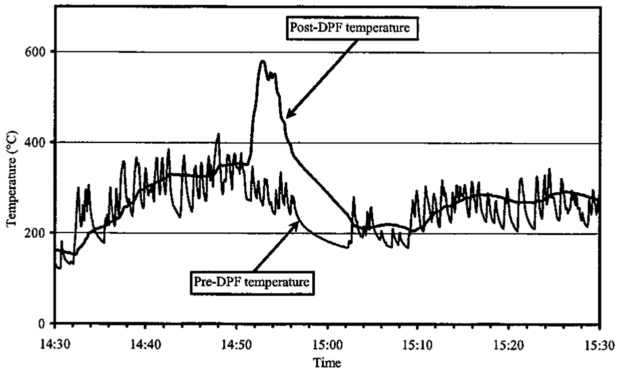

Figure 5. Regeneration on 20th August

The temperature histories of another regeneration event are shown in Figure 6; this event occurred on the 1st November. On this occasion there was a more sustained period of high temperature, i.e. above 250°C throughout the one-hour period shown and the mean temperature was falling when the regeneration was initiated. The regeneration appears to have been initiated at the temperature low point of 274.5°C just before an acceleration, which raised the pre-DPF temperature to 380.5°C. This was followed by another deceleration that caused the pre-DPF temperature to fall below 300°C and appears to have slowed the regeneration to the extent that the post-DPF temperature began to fall also. It is thus possible that if the engine were turned off at this point the regeneration would have been halted. However in this case there was a further acceleration which accelerated the reaction leading to a complete regeneration as is evidenced by the exotherm, giving a post-DPF temperature in excess of 600°C.

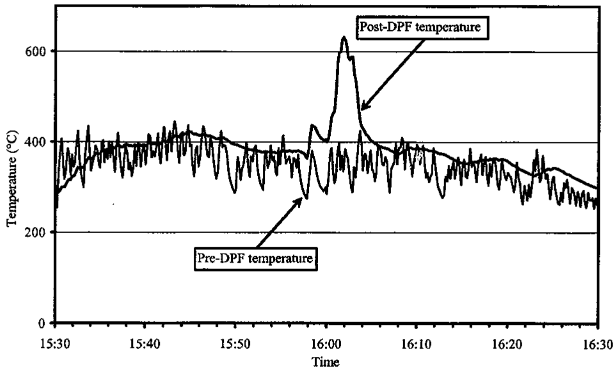

Figure 6. Regeneration on 1st November

At the time of writing this bus has covered over 50,000 km with the DPF fitted and no reported problems.

DOUBLE DECK BUS

Further testing was conducted on a MCW Metrobus double deck bus equipped with a Gardner 6LXB engine, details of which are given in Table 3. The particular vehicle used for this work was used for sightseeing tours in Stratford-upon-Avon and was an open topped version as shown in Figure 7. The bus was fitted with a 25.4 cm x 30.5 cm (10" x 12") catalysed SiC wall flow DPF, giving 15.4 ltrs of DPF volume to the 10.4 ltrs of naturally aspirated engine volume. The DPF was fitted in place of the conventional silencer unit and was again designed to provide the required noise attenuation to obviate the need for an additional silencer. This bus was also fitted with the on-board dosing system to add FBC to the fuel.

Table 3. Double deck bus engine details

Type	Gardner 6LXB
Cylinder arrangement	6 In-line
Bore	120.7 mm
Stroke	152.4 mm
Capacity	10450 cm^3
Compression ratio	15 : 1
Peak Power	1345 kW @ 1850 rev/min
Peak Torque	727 Nm @ 1000 rev/min
Emissions specification	Pre-Euro

Figure 7. Open topped double deck bus

This vehicle was tested to the Millbrook London Transport Bus (MLTB) cycle. This is a test cycle that has been specially developed to simulate the stop start operating conditions of a bus in Central London. Again the regulated emissions were measured from a bagged sample, but additionally modal gaseous emissions data were recorded along with the speciated NO_X by FTIR. The regulated emissions results are given in Appendix 2.

Due to the very transient nature of the MLTB cycle, with repeated hard accelerations, it tends to produce higher levels of NO_X emissions. For example a bus certified to Euro I limits would typically produce about 5 g/km of NO_X, on the FIGE cycle but would produce at least double that amount on the MLTB cycle. For this particular vehicle the cycle average NO_X emissions were 13.8 g/km for the OE exhaust system. The DPF reduced this by 2.3%, the HC and CO emissions were also reduced by 67% and 23% respectively. The modal HC emissions data are presented in Figure 8.

Due to the fact that this is a hot start test procedure the catalyst is already warm at the start of the test. Reductions in HC emissions are thus evident all through the test cycle.

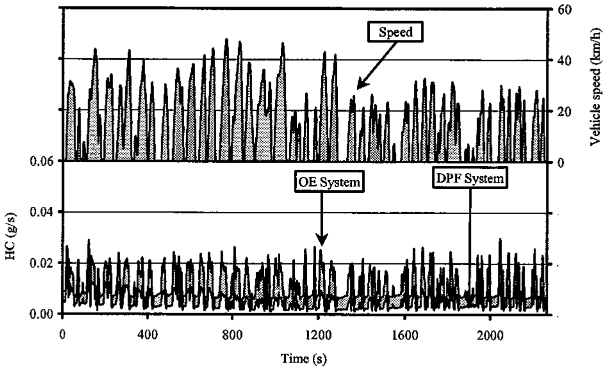

Figure 8. Modal HC emissions data

From the FTIR data, comparing the bus with the OE silencer to the case with the base metal catalysed DPF, the total NO_X emissions were within test repeatability but the NO_2 emissions were reduced by 59%. The second by second data for the NO_2 emissions are shown in Figure 9 along with the speed trace. Again the reductions appear to be fairly uniform throughout the cycle.

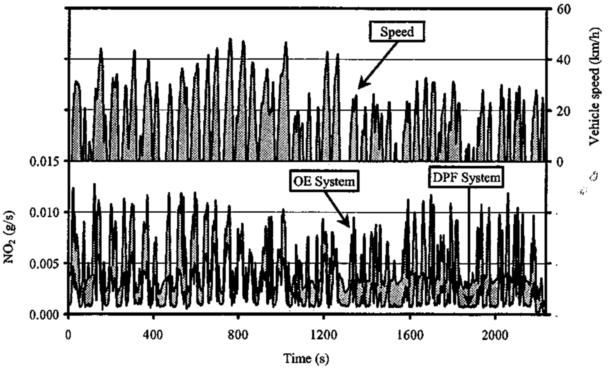

Figure 9. NO_2 emissions for double deck bus

The double deck bus was also fitted with thermocouples, a pressure transducer and data logger before being returned to active service. In this case the data logger was set to record data every 10 seconds while the engine was running. It was thus again possible to construct a pre-DPF temperature distribution in 10°C increments. This is shown in Figure 10.

Comparison of Figure 4 and Figure 10 shows that the double deck bus is operating at lower temperatures more frequently than the single deck bus, but again there is a secondary peak associated with idle. This secondary peak is at a slightly lower temperature for the double deck bus. The double deck bus spent 62.7% of the time with a pre-DPF temperature below 250°C, which was almost twice as much as the single deck bus. However the double deck bus spent a similar amount of time to the single deck bus with a pre-DPF temperature of greater than 350°C, namely 10.2% for the double deck bus compared with 12.4% for the single deck bus. This profile again ensured reliable regeneration of the DPF due to the presence of the FBC.

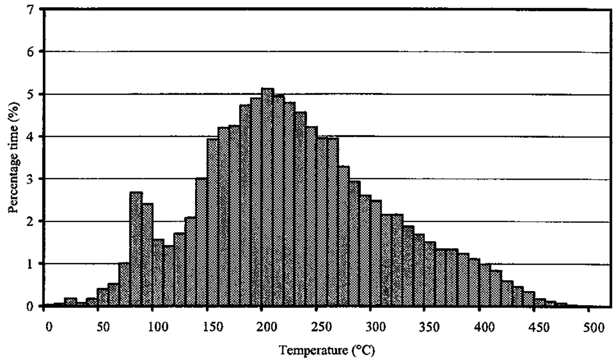

Figure 10. Temperature distribution for double deck bus

On this bus regenerations were occurring about every two days. Due to the different duty cycle of this bus this equates to a much lower distance of approximately 120 km between regenerations, but because of the higher PM emission rate of this bus, this does lead to similar soot loadings within the DPF. The regulated emissions test results for the OE system were 1.025 g/km of PM, which equates to approximately 123 g of soot over 120 km, or 8.0 g/ltr of DPF volume.

The pre-DPF and post-DPF temperature histories of one of the regular regeneration events are illustrated in Figure 11. This particular regeneration took place on 22nd October and follows the classic pattern for regenerations in an FBC based filter system.

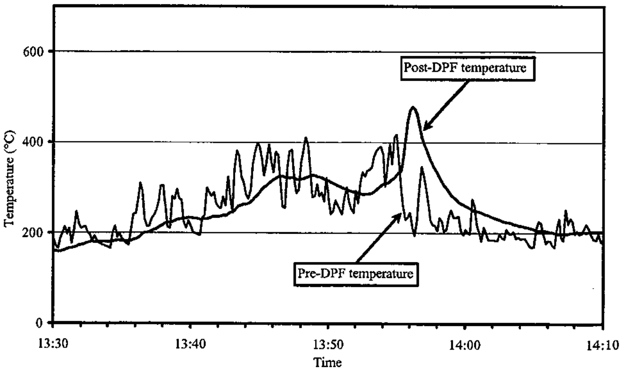

Figure 11. Regeneration on 22nd October

A period of elevated pre-DPF temperature raises the temperature of the DPF itself, and thus the trapped soot. A deceleration then raises the oxygen level in the gas stream leading to the sustained oxidation of the trapped soot. Due to the lower distance accumulation rate on this sightseeing bus the total distance covered to date is only about 3000km.

CONCLUSION

- Although DPFs have been widely promoted as a very effect means of reducing the soot emissions from urban buses, there are still questions regarding the effect some DPF technologies have upon the emissions of NO_2.
- The duty cycle and emissions characteristics of certain buses also make them a challenge for some DPF regeneration strategies.
- By the use of a base metal catalytic coating both HC and CO are effectively oxidised without promoting the oxidation of NO to NO_2.
- By careful selection of the base metal catalyst the reduction of NO_2 by the HC and the trapped soot can be maximised leading to a significant decrease in the overall emissions of NO_2.
- The use of a fuel borne catalyst in conjunction with the base metal catalysed DPF ensures regeneration of the DPF under a variety of duty cycles.

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APPENDIX 1

TEST PURPOSE:-	***O E EXHAUST SYSTEM***
DATE	25-JUL-03
VEHICLE NO	L228SWM
VEHICLE TYPE	DENNIS DART
ENGINE	CUMMINS 97 kW
CERTIFICATION LEVEL	EURO 1
TRANS TYPE	AUTO
FUEL TYPE	ULSD
FUEL DENSITY @15°C	0.836
POWER ABSORBED	16.08 kWh
DISTANCE TRAVELLED	29.08 km

DYNAMOMETER SETTINGS	
INERTIA	6866 kg
F^o	197.2 N
F^1	-1.570 N/ (km/ h)
F^2	0.1659 N/ (km/ h) ^{2}
F^3	0.00080 N/ (km/ h) ^{3}

ROAD CURVE COEFFICIENTS USED	
TEST WEIGHT	6866 kg
F^o	673.4 N
F^2	0.2195 N/ (km/ h) ^{2}

Test No. ***#1***							Fuel Cons
	UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
FIGE Drive Cycle	grammes	20.581	60.097	148.21	21338.0	17.820	27.88
Combined result	g/ km	0.708	2.067	5.096	733.7	0.613	litres/ 100km
Equivalent	**g/kWh**	1.280	3.738	9.218	1327.2	1.108	421.61
Limit For VED	**g/kWh**					**0.160**	g/ kWh
	PASS/ FAIL					FAIL	
	%OF LIMIT					693%	

TEST PURPOSE:-	***5.8L DPF***
DATE	25-JUL-03
VEHICLE NO	L228SWM
VEHICLE TYPE	DENNIS DART
ENGINE	CUMMINS 97 kW
CERTIFICATION LEVEL	EURO 1
TRANS TYPE	AUTO
FUEL TYPE	ULSD
FUEL DENSITY @15°C	0.836
POWER ABSORBED	15.85 kWh
DISTANCE TRAVELLED	28.98 km

DYNAMOMETER SETTINGS	
INERTIA	6,866 kg
F^0	197.2 N
F^1	-1.570 N/ (km/ h)
F^2	0.1659 N/ (km/ h)^2
F^3	0.000796 N/ (km/ h)^3

ROAD CURVE COEFFICIENTS USED	
TEST WEIGHT	6,866 kg
F^0	673.4 N
F^2	0.2195 N/ (km/ h)^2

Test No. ***#1***	UNITS	HC	CO	NOx	CO2	PM	Fuel Cons (Carb Bal)
FIGE Drive Cycle	grammes	1.308	13.308	130.87	21052.0	2.298	27.43
Combined result	g/ km	0.045	0.459	4.515	726.4	0.079	litres/ 100km
Equivalent	**g/kWh**	0.083	0.840	8.258	1328.3	0.145	419.34
Limit For VED	**g/kWh**					**0.160**	g/ kWh
	PASS/ FAIL					PASS	
	%OF LIMIT					91%	
Reduction with DPF (%)		**93.55**	**77.54**	**10.42**	**-0.09**	**86.92**	**0.54**

APPENDIX 2

Customer:	**Adastra**
Customer Address:	**Ellesmere Port, Cheshire**
Test Purpose:	**PM Trap Evaluation - Baseline Tests**

Vehicle No:	***BYX 219V***
Vehicle Type:	***MCW Metrobus***
Engine:	***Gardner***
Transmission:	***Auto***
Fuel Type:	***ULSD***
Fuel density	***0.836***

DYNAMOMETER SETTINGS	
INERTIA	12648 kg
F^{o}	344.30 N
F^{1}	-12.025 N/kmh
F^{2}	0.69150 N/kmh^{2}
F^{3}	-0.001944 N/kmh^{3}

Test No.	***#1***	***09-Oct-03***						Fuel Cons
		UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
Phase 1	*Outer London*	grammes	16.911	32.317	86.834	7123.8	5.326	42.61
Phase 2	*Inner London*	grammes	9.898	16.658	45.014	3628.6	3.655	55.52
Combined result		g/km	3.011	5.501	14.809	1207.7	1.009	litres/100km
								46.24

Test No.	***#2***	***09-Oct-03***						Fuel Cons
		UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
Phase 1	*Outer London*	grammes	17.763	32.939	79.555	7065.5	5.544	42.00
Phase 2	*Inner London*	grammes	10.044	16.913	40.141	3553.0	3.160	54.23
Combined result		g/km	3.106	5.568	13.368	1185.9	0.972	litres/100km
								45.43

Test No.	***#3***	***09-Oct-03***						Fuel Cons
		UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
Phase 1	*Outer London*	grammes	18.111	33.110	77.725	7000.9	6.086	41.71
Phase 2	*Inner London*	grammes	10.529	16.537	39.759	3541.9	3.705	54.18
Combined result		g/km	3.205	5.555	13.146	1179.7	1.096	litres/100km
								45.21

Average of Combined Tests (g/km)	3.107	5.541	13.774	1191.1	1.025	45.63
Standard Deviation/Mean x100	2.54	0.53	5.35	1.01	5.05	0.97

Customer:	**Adastra**
Customer Address:	**Ellesmere Port, Cheshire**
Test Purpose:	**PM Trap Evaluation - 15 Litre PM Trap**

Vehicle No:	***BYX 219V***
Vehicle Type:	***MCW Metrobus***
Engine:	***Gardner***
Transmission:	***Auto***
Fuel Type:	***ULSD***
Fuel density	***0.836***

DYNAMOMETER SETTINGS	
INERTIA	12648 kg
F°	344.30 N
F^1	-12.025 N/kmh
F^2	0.69150 N/kmh^2
F^3	-0.001944 N/kmh^3

Test No.	***#1***	***09-Oct-03***						Fuel Cons
		UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
Phase 1	*Outer London*	grammes	5.085	24.511	83.945	7422.3	0.467	42.69
Phase 2	*Inner London*	grammes	3.800	13.555	41.418	3579.4	0.269	52.68
Combined result		g/km	0.967	4.141	13.638	1196.9	0.080	litres/100km
								45.50

Test No.	***#2***	***09-Oct-03***						Fuel Cons
		UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
Phase 1	*Outer London*	grammes	7.964	27.033	79.653	7158.2	0.792	42.28
Phase 2	*Inner London*	grammes	0.959	13.657	40.287	3564.9	0.303	52.83
Combined result		g/km	0.990	4.516	13.313	1190.2	0.122	litres/100km
								45.28

Test No.	***#3***	***09-Oct-03***						Fuel Cons
		UNITS	**HC**	**CO**	**NOx**	**CO2**	**PM**	(Carb Bal)
Phase 1	*Outer London*	grammes	6.168	24.470	80.547	7110.7	0.527	41.74
Phase 2	*Inner London*	grammes	3.800	12.992	39.690	3488.9	0.289	53.37
Combined result		g/km	1.112	4.178	13.409	1182.0	0.091	litres/100km
								44.96

Average of Combined Tests (g/km)	1.023	4.278	13.453	1189.7	0.098	45.25
Standard Deviation/Mean x100	6.21	3.95	1.01	0.51	17.98	0.49
Reduction with DPF (%)	**67.08**	**22.79**	**2.33**	**0.12**	**90.49**	**0.83**