



**Stephenson**

Environmental Management Australia

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**VEHICLE EMISSION TESTING – BEFORE AND AFTER CENTRON ADDITIVE**

**CENTRON FUELS PTY LTD**

**BAULKHAM HILLS**

**PROJECT NO.: 4310/S15569/09**

**DATE OF SURVEY: MARCH 2009**

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## 1 INTRODUCTION

Stephenson Environmental Management Australia (SEMA) was requested by Centron Fuels Pty Ltd to assess the vehicle emissions before and after the Centron additive was added to the fuel. The vehicle was an Isuzu FRR550 first registered in September 2000 and operated by Perry Taylor Transport.

The "before" tests were conducted on 5 March 2009 and the "after" tests were conducted on 19 March 2009. After the "before" tests were completed the Centron fuel additive was added to the fuel tank. The "after" test was conducted two weeks later after the truck had consumed two full tanks of diesel fuel that is approximately 2000 litres.

The "before" test was conducted over a 5 kilometre (km) trip from Unit 7/2 Holker Street Newington around the Sydney Olympic Park precinct.

The "after" test was conducted over a 5 kilometre (km) trip from Unit 7/2 Holker Street Newington around the Sydney Olympic Park precinct and onto the M4 via Silverwater Road.

The tests were undertaken from the engine exhaust.

The objectives of the tests were to evaluate emissions during a typical run through all forward operating gears and various engine revolutions per minute (RPM) ranges over each test period.

The emission was assessed for the following components:

- Particulates (Total Solid Particulate matter)
- Smoke - Ringlemann Number
- Oxides of Nitrogen (NO<sub>x</sub>)
- Sulphur Dioxide (SO<sub>2</sub>)
- Carbon Dioxide (CO<sub>2</sub>)
- Carbon Monoxide (CO)
- Oxygen (O<sub>2</sub>)

## **2 VEHICLE OPERATING CONDITIONS**

The vehicle was operated by its routine driver Perry Taylor under a range of controlled engine operating conditions. Exhaust emissions were measured continuously during the periods of the emissions test.

Specific engine RPM were nominated and recorded at critical operating phases of each test. These conditions were repeated for the second round of testing that is post Centron addition.

Some additional higher load work was added to the second round of testing when it became apparent that the peak NO<sub>x</sub> emission appeared lower than the first round of emissions testing.

The owner/driver of the vehicle anecdotally reported that vehicle appeared to have more power under routine load conditions.

### 3 EMISSION TEST RESULTS

#### 3.1 INTRODUCTION

SEMA completed the sampling for all parameters tested and analysis of Total Solid Particulate matter (TSP). SEMA is NATA accredited for this sampling and analysis, Accreditation No. 15043.

Refer to Appendix C for the Certificates of Analysis.

The emission test results are summarised in Table 3-1 below and detailed in Sections 3.2 to 3.7. Appendix B Figure B-1 to Figure B-4 illustrates graphically the continuous logged record of nitrogen oxides (NO<sub>x</sub>) and Carbon Monoxide (CO) verse RPM for the two tests conducted.

The TSP samples were sampled at a set sampling rate. Due to the variability of engine gas flow rates and engine revolutions associated with gear changing particle sampling was performed at set sampling rates rather than isokinetic sampling rates.

The sample location is presented in Appendix D.

**TABLE 3-1 AVERAGE EMISSION CONCENTRATION TEST RESULTS**

Pollutant	Before Additive Average Emission Concentration (mg/m <sup>3</sup> )	After Additive Average Emission Concentration (mg/m <sup>3</sup> )
Carbon Monoxide (CO)	285	208
Carbon Dioxide (CO <sub>2</sub> ) (%)	2.3	2.4
Oxides of Nitrogen (NO <sub>x</sub> )	502	423
Sulphur Dioxide	11	< 3
Total Solid Particulate (TSP) matter	38.4	12.3

Key:

% = percentage

mg/m<sup>3</sup> = milligrams per cubic metre at 0°C and 1 atmosphere

## **3.2 PARTICULATE MATTER (PM)**

### **3.2.1 BEFORE ADDITIVE**

The Particulate Matter emission concentration was 38.4 milligrams per cubic metre ( $\text{mg}/\text{m}^3$ ) for Before Additive. Refer to Appendix A, Table A-1 for detailed results in table format.

### **3.2.2 AFTER ADDITIVE**

The Particulate Matter emission concentration was 12.3  $\text{mg}/\text{m}^3$  for After Additive. Refer to Appendix A, Table A-1 for detailed results in table format.

## **3.3 OXIDES OF NITROGEN ( $\text{NO}_x$ )**

### **3.3.1 BEFORE ADDITIVE**

The  $\text{NO}_x$  (expressed as  $\text{NO}_2$ ) emission concentration for the test period ranged from 7 to 518 parts per million (ppm) (14 to 1,063  $\text{mg}/\text{m}^3$ ) and averaged 244 ppm (502  $\text{mg}/\text{m}^3$ ).

Refer to Table 3-1 and Appendix B Figure B-1 for detailed results in tabulated and graphical formats respectively.

### **3.3.2 AFTER ADDITIVE**

The  $\text{NO}_x$  (expressed as  $\text{NO}_2$ ) emission concentration for the test period ranged from 1 to 338 ppm (2 to 694  $\text{mg}/\text{m}^3$ ) and averaged 206 ppm (423  $\text{mg}/\text{m}^3$ ).

Refer to Table 3-1 and Appendix B Figure B-3 for detailed results in tabulated and graphical formats respectively.

## **3.4 SULPHUR DIOXIDE**

### **3.4.1 BEFORE ADDITIVE**

The  $\text{SO}_2$  emission concentration for the test period ranged from less than 1 to 9 ppm (less than 3 to 26  $\text{mg}/\text{m}^3$ ) and averaged 4 ppm (11  $\text{mg}/\text{m}^3$ ).

### **3.4.2 AFTER ADDITIVE**

The  $\text{SO}_2$  emission concentration for the test period ranged from less than 1 to 1 ppm (less than 3 to 3  $\text{mg}/\text{m}^3$ ) and averaged less than 1 ppm (less than 3  $\text{mg}/\text{m}^3$ ).

### **3.5 CARBON MONOXIDE (CO)**

#### **3.5.1 BEFORE ADDITIVE**

The CO emission concentrations measured ranged from 4 to 400 mg/m<sup>3</sup> with an average of 285 mg/m<sup>3</sup>.

Refer to Appendix B Figure B-2 for graphical representation of the results.

#### **3.5.2 AFTER ADDITIVE**

The CO emission concentrations measured ranged from less than 1.3 to 316 mg/m<sup>3</sup> with an average of 208 mg/m<sup>3</sup>.

Refer to Appendix B Figure B-4 for graphical representation of the results.

### **3.6 CARBON DIOXIDE (CO<sub>2</sub>)**

#### **3.6.1 BEFORE ADDITIVE**

The CO<sub>2</sub> emission concentrations measured ranged from 0.1 to 3.5%, with an average of 2.3%.

#### **3.6.2 AFTER ADDITIVE**

The CO<sub>2</sub> emission concentrations measured ranged from 0.0 to 4.2%, with an average of 2.4%.

### **3.7 OXYGEN (O<sub>2</sub>)**

#### **3.7.1 BEFORE ADDITIVE**

The O<sub>2</sub> emission concentrations measured ranged from 16.5 to 21.0%, with an average of 18.1%.

#### **3.7.2 AFTER ADDITIVE**

The O<sub>2</sub> emission concentrations measured ranged from 15.5 to 21.1%, with an average of 17.9%.

### **3.8 SMOKE – RINGLEMANN ASSESSMENT**

The emission from the stack was measured to determine the blackness of smoke using a visual blackness technique. The technique used was the standard Ringlemann chart in accordance with AS 3543-1989 and DECC NSW TM-16.

#### **3.8.1 BEFORE ADDITIVE**

Several times white smoke from exhaust was visible, from first-second gear low speeds at various stages. Ringlemann ranged between 1 and 2. No black smoke - which maybe due to the fact the vehicle not undergoing the same hard acceleration onto the M4 as the second test.

#### **3.8.2 AFTER ADDITIVE**

No white smoke. Black smoke noticeable under hard acceleration whilst heading up on-ramp to M4. Ringlemann 3 for approximately 3 seconds.

## 4 CONCLUSIONS

From the data presented and test work conducted on the engine exhaust serving the vehicle Isuzu FRR550 operated by Perry Taylor Transport, Table 4-1 summarises the results for before and after the Centron Fuel additive was added to the fuel.

**TABLE 4-1 AVERAGE EMISSION CONCENTRATION TEST RESULTS**

<b>Pollutant</b>	<b>Before Additive Average Emission Concentration (mg/m<sup>3</sup>)</b>	<b>After Additive Average Emission Concentration (mg/m<sup>3</sup>)</b>
Carbon Monoxide (CO)	285	208
Carbon Dioxide (CO <sub>2</sub> ) (%)	2.3	2.4
Oxides of Nitrogen (NO <sub>x</sub> )	502	423
Sulphur Dioxide	11	< 3
Total Solid Particulate (TSP) matter	38.4	12.3

Key:

% = percentage  
 mg/m<sup>3</sup> = milligrams per cubic metre at 0°C and 1 atmosphere

In essence, the data presented in Table 4-1 shows that in these comparative emission tests, that after the addition of Centron to two full tanks of fuel and some 2000 kilometres of travel that:

- NO<sub>x</sub>, CO and TSP emissions all decreased.
- It is noted that this is unusual in conventional engine management with NO<sub>x</sub> and CO generally being inversely proportional. This may imply that Centron has modified the burn rate of the fuel during combustion.

## 5 TEST METHODS

### 5.1 PARTICULATES MATTER

*(NSW DECC Test Method 15 and Australian Standards AS 4323.2, 1995)*

The Membrane Filtration Method utilising equipment manufactured by the Pall Life Sciences was used for the soot sampling from the discharge exhaust.

Samples were collected at a constant rate from the exhaust of the engine, and analysed in accordance with Australian Standard (AS) 4323, 1995 Parts 2 and DECC NSW Approved Methods of Sampling.

### 5.2 EXHAUST GAS TEMPERATURE

*(NSW DECC TM- 2, 3 & 4 and USEPA Methods 2, 3 & 4)*

The exhaust gas temperature was measured using a Digital thermometer (0-1200°C) connected to a chromel/alumel (K-type) thermocouple probe.

### 5.3 CONTINUOUS GASEOUS ANALYSIS

Sampling and analysis of exhaust gas were performed using one of Stephenson Environmental Management Australia's mobile combustion and environmental monitoring laboratories. Emission gases were distributed to the analysers via a manifold. Flue gas from each stack was pumped continuously. The following components of the laboratory were relevant to this work:

Gas Transfer	Technical Heaters PTFE sample lines Temperature Controllers, condensor
CO, CO <sub>2</sub> , O <sub>2</sub> , NO <sub>x</sub>	NSW EPA TM 32, 24 & 11, USEPA Method 10 3A & 7E Testo 350 combustion analyser BOC Special Gas Mixtures relevant for each analyser. Instrument calibrations were performed at the start and finish of sampling on each stack.
QA/QC	Calibration (Zero/Span) checks Sample line integrity calibration check

## 5.4 ACCURACY

All results are quoted on a dry basis. SEMA has adopted the following (Table 5-1) uncertainties for various stack testing methods.

**TABLE 5-1 ESTIMATION OF MEASUREMENT UNCERTAINTY**

Pollutant	Methods	Uncertainty
Nitrogen Oxides	TM-11, USEPA 7E	15% <sup>+</sup>
Oxygen and Carbon Dioxide	TM-24, TM-25, USEPA 3A	1% actual <sup>+</sup>
Particulate > 20 mg/m <sup>3</sup>	TM-15, AS4323.2, USEPA 5 & 17	15% <sup>+</sup>
Particulate < 20 mg/m <sup>3</sup>	TM-15, AS4323.2, USEPA 5 & 17	50% <sup>+</sup>
Velocity	AS4323.1, TM-2, USEPA 2a,2c,	5% <sup>+</sup>

Key:

- \* = range of uncertainties given
- + = The uncertainties quoted have been determined @ 95% level of Confidence level (i.e. by multiplying the repeatability standard deviation by a co-efficient equal to 1.96) (Source - Measurement Uncertainty)

Sources: *Measurement Uncertainty - implications for the enforcement of emission limits* by Maciek Lewandowski (Environment Agency) & Michael Woodfield (AEAT) UK [www.cem2004.it/art/3\\_6.pdf](http://www.cem2004.it/art/3_6.pdf)

*Technical Guidance Note (Monitoring) M2 Monitoring of stack emissions to air Environment Agency Version 3.1 June 2005.*

*Note: SO 9096 is for 20-1000 mg/m<sup>3</sup> which AS4323.2 is based on. Note DSEN 13284-1 testing for < 5 mg/m<sup>3</sup> correlates to 5mg/m<sup>3</sup> with most quoted uncertainties of ± 5.3mg/m<sup>3</sup> @ 6.4 mg/m<sup>3</sup>. From Clean Air Engineering in the United States the lowest practical limit of USEPA M5 is 5 mg/m<sup>3</sup> under lab conditions.*

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## APPENDIX A – EMISSION TEST RESULTS

### Glossary:

%	=	percent
°C	=	Degrees Celsius
am <sup>3</sup> /min	=	cubic metre of gas at actual conditions per minute
Normal Volume (m <sup>3</sup> )	=	cubic metre at 0°C and 760 mm pressure and 1 atmosphere
am <sup>3</sup>	=	cubic metre of gas at actual conditions
g/g mole	=	grams per gram mole
g/s	=	grams per second
hrs	=	hours
kg/m <sup>3</sup>	=	kilograms per cubic metre
kPa	=	kilo Pascals
m <sup>2</sup>	=	square metre
m/s	=	metre per second
m <sup>3</sup> /sec	=	cubic metre per second at 0°C and 1 atmosphere
mg	=	milligrams
mg/ m <sup>3</sup>	=	milligrams per cubic metre at 0°C and 1 atmosphere
O <sub>2</sub>	=	Oxygen

### Abbreviations of Parameters

TSP	=	Total Solid Particulates
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**TABLE A - 1 EMISSION TEST RESULTS – PARTICULATE MATTER**

<b>Emission Test Results</b>	<b>TSP</b>	<b>TSP</b>
Project Number	4310	4310
Project Name	Centron Fuels	Centron Fuels
Test Location	Perry Taylor 9/2000 ISUZU FRR550	Perry Taylor 9/2000 ISUZU FRR550
Date	5-Mar-09	19-Mar-09
<b>RUN</b>	<b>1A</b>	<b>2A</b>
Sample Start Time (hrs)	9:36	9:40
Sample Finish Time (hrs)	10:36	10:40
Sample Location (Inlet/Exhaust)	Exhaust	Exhaust
Stack Temperature (°C)	113.4	141.8
Stack Cross-Sectional area (m <sup>2</sup> )	0.008	0.008
Total Stack Pressure (kPa)	101.30	101.30
Analysis	TSP	TSP
Method	TM-15	TM-15
SEMA Lab Number	716577	716648
Mass In Sample (mg)	12.43	4.48
Air Volume Sampled (am <sup>3</sup> )	0.35	0.39
Normal Sample Volume (m <sup>3</sup> )	0.32	0.36
Concentration at Stack O <sub>2</sub> (mg/m <sup>3</sup> )	38.40	12.33
Moisture Content (% by volume)	6.5	1.3
Molecular Weight Dry Stack Gas (g/g-mole)	29.092	29.100
Dry Gas Density (kg/m <sup>3</sup> )	1.30	1.30
EPL Limit (mg/m <sup>3</sup> )	No Limit	No Limit
Isokinetic Sampling Rate (%)	NA	NA
Sample Storage Period	3 months	3 months
Sampling Performed by	PC / PWS	PC / PWS
Sample Analysed by (Laboratory)	SEMA	SEMA
Calculations Entered by	MB	MB
Calculations Checked by	JW	JW

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**APPENDIX B – GRAPHICAL REPRESENTATION OF CONTINUOUS PLOT**

FIGURE B - 1 NITROGEN OXIDES VS RPM CONTINUOUS MONITORING RESULTS – “BEFORE” CENTRON ADDITIVE

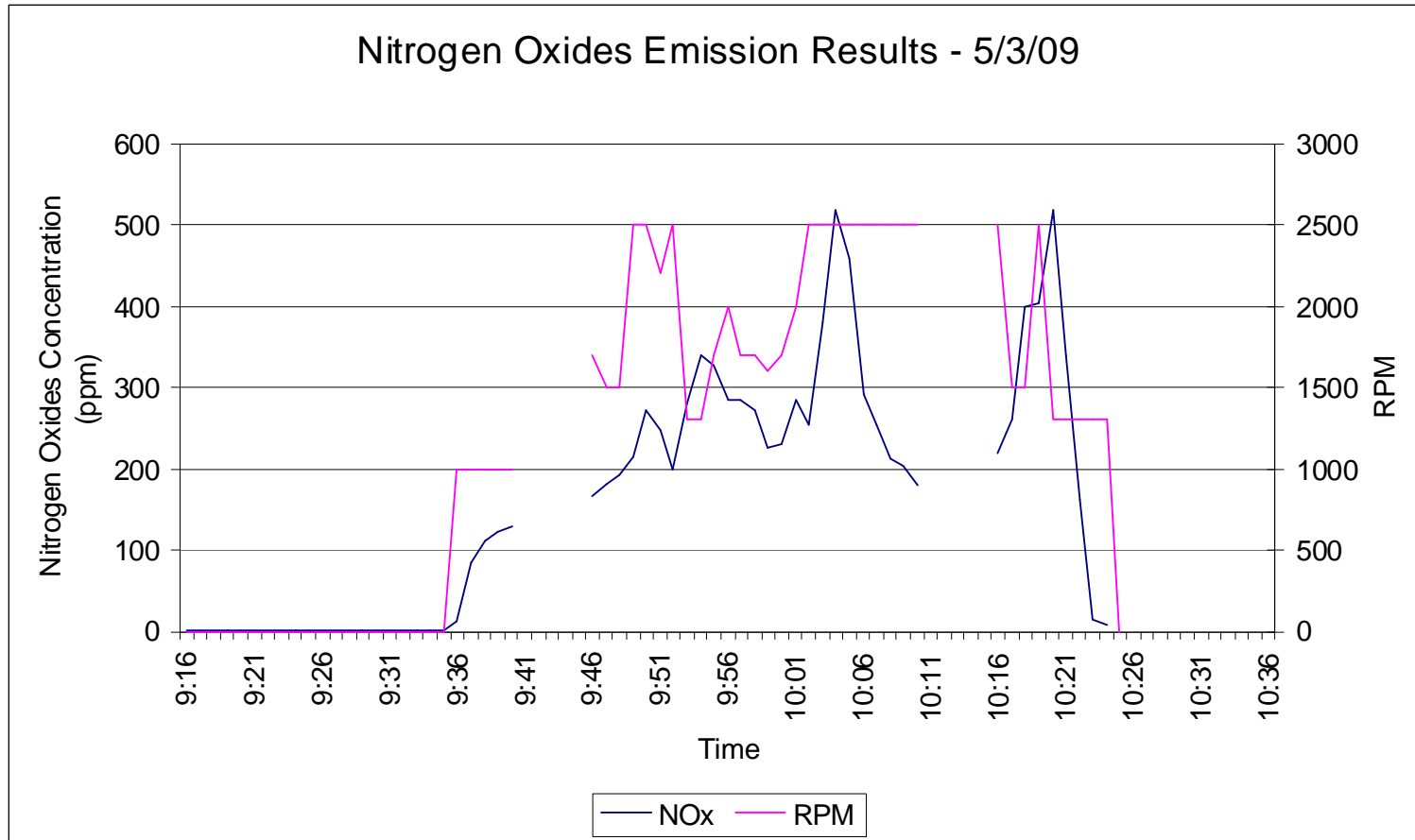


FIGURE B - 2 CARBON MONOXIDE VS RPM CONTINUOUS MONITORING RESULTS – “BEFORE” CENTRON ADDITIVE

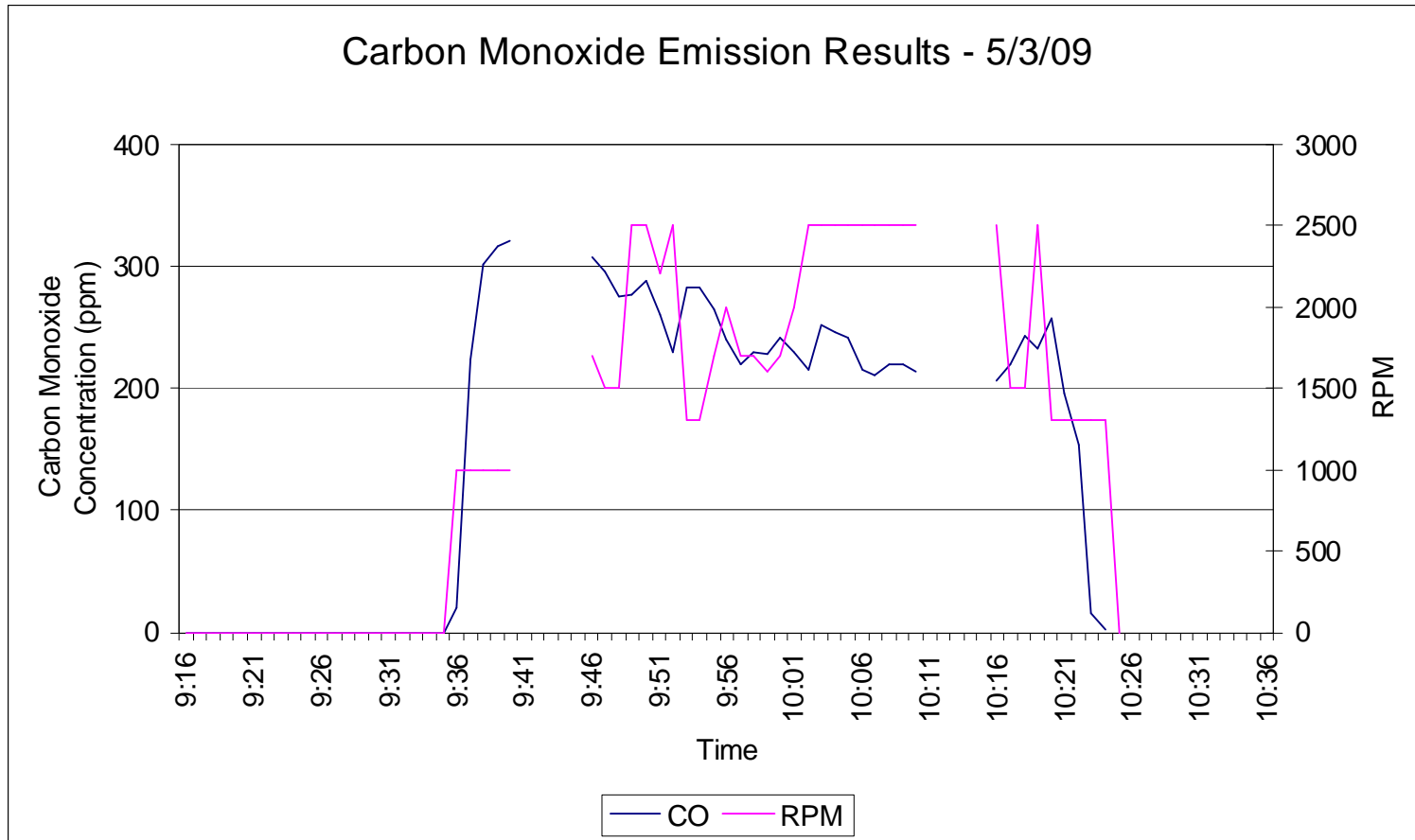


FIGURE B - 3 NITROGEN OXIDES VS RPM CONTINUOUS MONITORING RESULTS – “AFTER” CENTRON ADDITIVE

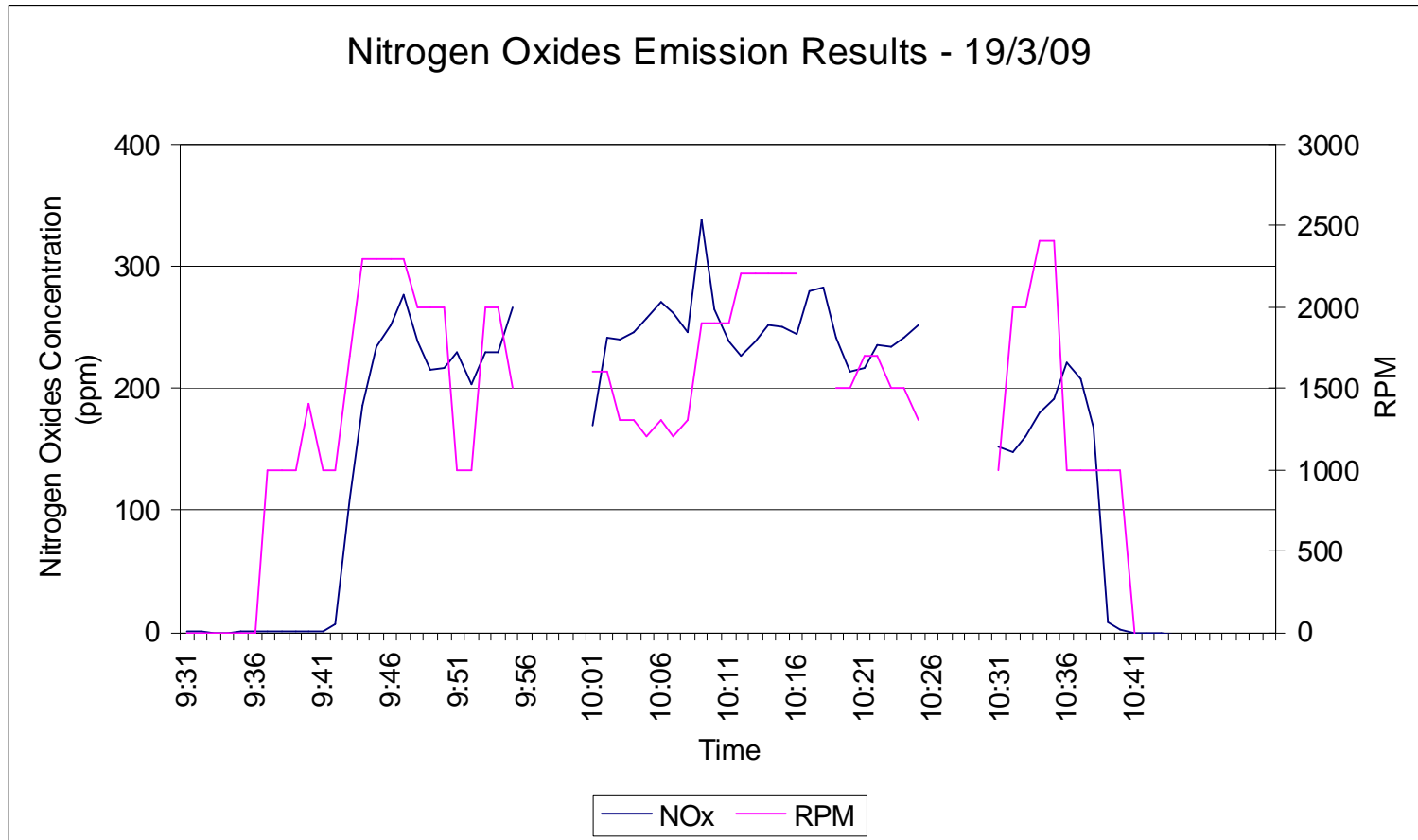
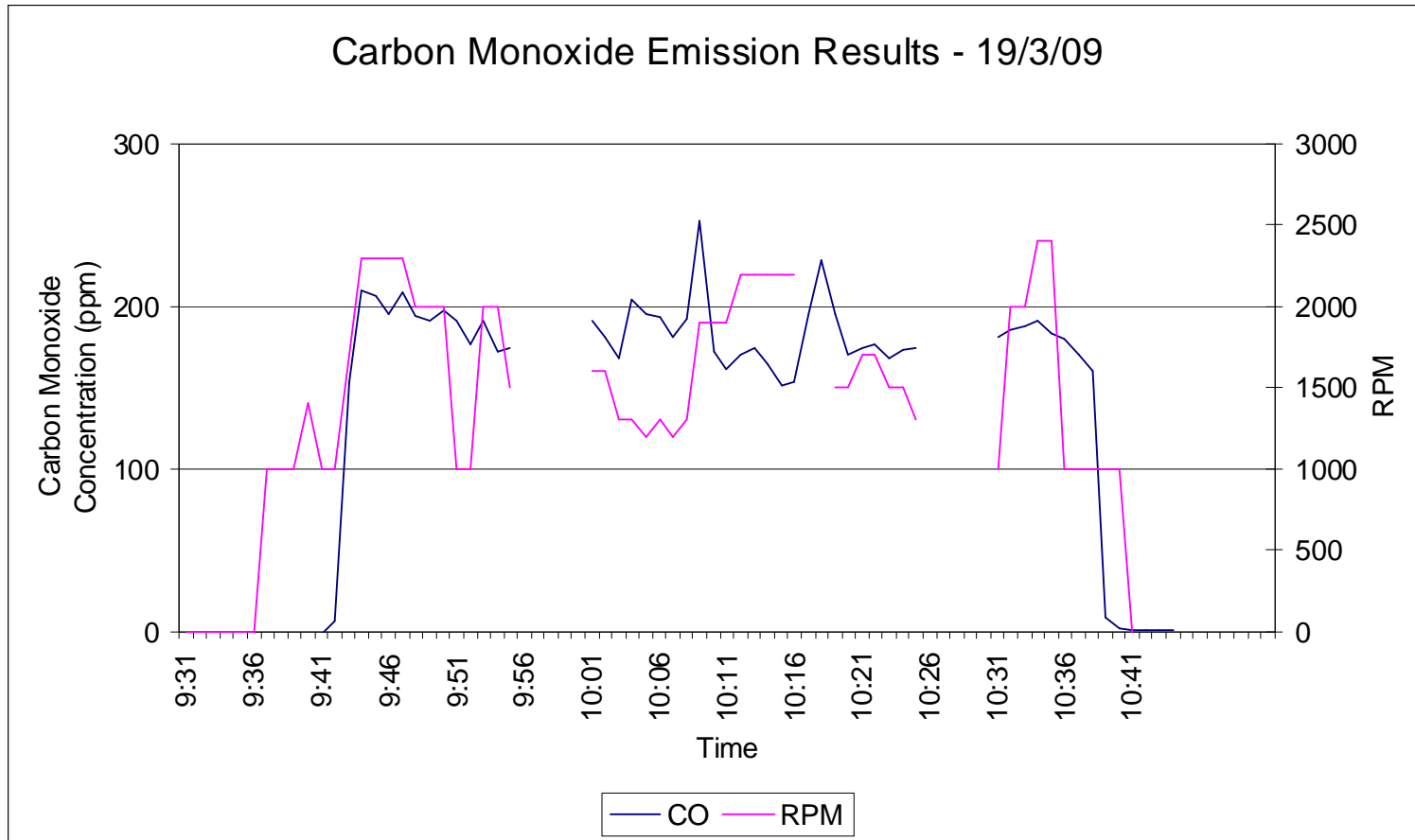


FIGURE B - 4 CARBON MONOXIDE VS RPM CONTINUOUS MONITORING RESULTS – “AFTER” CENTRON ADDITIVE



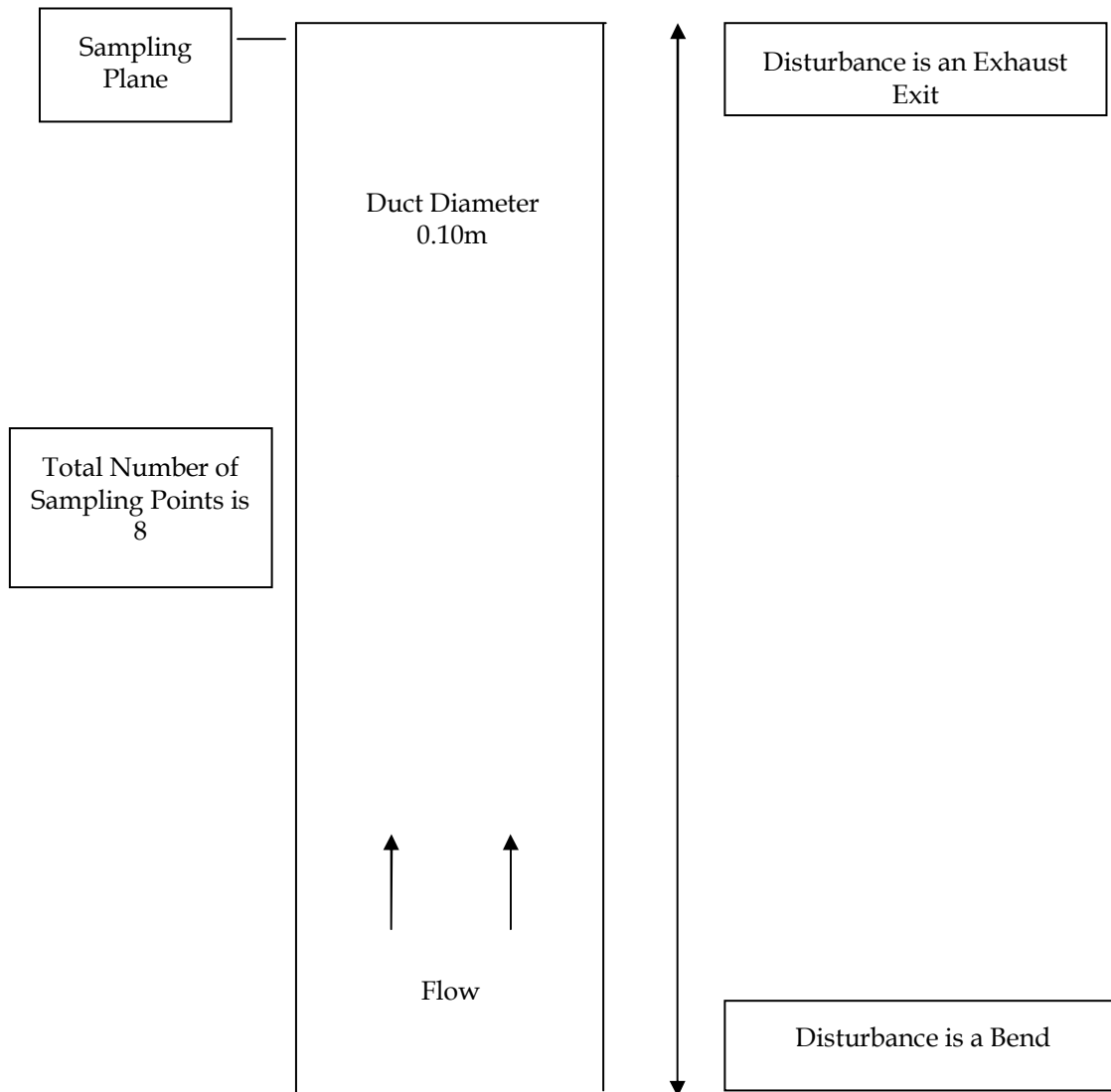
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**APPENDIX C – CERTIFICATES OF ANALYSIS**

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## **APPENDIX D – SAMPLE LOCATION**

FIGURE D - 1 SAMPLE LOCATION



In the absence of cyclonic flow activity ideal sampling plane conditions will be found to exist at 6-8 duct diameters downstream and 2-3 duct diameters upstream from a flow disturbance. No flows were measured due to access restrictions on a moving vehicle.

The TSP samples were sampled at a set flow rate due to the variations in exhaust gas velocity caused by the changing engine speeds which do not allow sufficient time to adjust flows for isokinetic sampling. The very small particle size of solid carbon diesel engine emissions generally means that isokinetic sampling rates are not critical for representative TSP collection.