AIR & EMISSIONS TESTING GROUP

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Stack Emissions Testing Report

Operator / Company
Hargreaves Services Plc

Site:
Featherstone

Release Point:
Engine 2 (90% loading)

Sampling Date/s:
8th July 2010

Job Number:
LDO 0044

Report Date: Version:	15th July 2010 2
Report By: MCERTS Number: MCERTS Level: Technical Endorsements:	Paul Adamczyk MM 04 547 MCERTS Level 2 - Team Leader 1, 2, 3 & 4
Report Approved By: MCERTS Number: Business Title: Technical Endorsements: Signature:	Andrew Palliser MM 03 161 MCERTS Level 2 - Business Manager 1, 2, 3 & 4 

1015

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EXECUTIVE SUMMARY

Stack Emissions Monitoring Objectives

Hargreaves Services Plc operates a power generation diesel engine at Featherstone

Environmental Scientifics Group Limited were commissioned by Hargreaves Services Plc to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

Plant

Engine 2 (90% loading)

Operator

Hargreaves Services Plc
Rocpower
Common Side Lane
Featherstone
WF7 6RA

Stack Emissions Monitoring

Environmental Scientifics Group Limited - Stockport Laboratory
52 Offerton Industrial Estate
Hempshaw Lane
Stockport
SK2 5TJ
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
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This test report replaces and supersedes version 1 dated 14th July 2010

EXECUTIVE SUMMARY

Emissions Summary

Parameter	Units	Result	Uncertainty +/-	Limit
Total Particulate Matter	mg/m³	98	8.9	-
Particulate Emission Rate	g/hr	307	28	-
PM_{10}	mg/m³	80	3.0	-
PM_{10} Emission Rate	g/hr	284	11	-
$PM_{2.5}$	mg/m³	74	2.9	-
$PM_{2.5}$ Emission Rate	g/hr	264	10	-
Oxides of Nitrogen (as NO2)	mg/m³	4409	551	-
Oxides of Nitrogen (as NO2) Emission Rate	g/hr	13439	1679	-
Oxygen	% v/v	12.8	0.51	-
Moisture	%	9.8	0.52	-
Stack Gas Temperature	°C	364	-	-
Stack Gas Velocity	m/s	38	-	-
Gas Volumetric Flow Rate (Actual)	m³/hr	17322	-	-
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	7424	-	-
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	6695	-	-
Gas Volumetric Flow Rate (@ref conditions)	m³/hr	3048	-	-

ND = None Detected,

Results at or below the limit of detection are highlighted by bold italic text.

The above volumetric flow rate is calculated using data from the preliminary survey. Mass emissions for non isokinetic tests are calculated using these values. For all isokinetic testing the mass emission is calculated using test specific values.

Reference conditions are 273K, 101.3kPa, dry gas, 3% Oxygen.

EXECUTIVE SUMMARY

Monitoring Times

Parameter	Sampling Date	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	08 July 2010	14:45 - 14:57	12 minutes
PM_{10} Run 1	08 July 2010	15:38 - 15:50	12 minutes
$PM_{2.5}$ Run 1	08 July 2010	15:38 - 15:50	12 minutes
Combustion Gases	08 July 2010	18:41 - 19:41	60 minutes

EXECUTIVE SUMMARY

Process Details

Parameter	Process Details
Process Status	Normal
Percentage of capacity or Tonnes / Hour	90% Loading
Continuous or Batch Process	Continuous
Feedstock (if applicable)	-
Abatement System	None
Abatement System Running Status	N/A
Fuel	Tall Oil
Plume Appearance	Plume Visible

EXECUTIVE SUMMARY

Monitoring Methods

The selection of standard methods employed by Scientifics is determined, wherever possible by the hierarchy of method selection outlined in Environment Agency Technical Guidance Document (Monitoring) M2. i.e. CEN, ISO, BS, US EPA etc.

The tables below summarise the monitoring methods, techniques and technical procedures employed, and details any deviations from the aforementioned hierarchy:

Sampling Methods with Subsequent Analysis

Species	Standard Method	Scientifics Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	MU of Method +/- %	MU +/- %
TPM	BS EN 13284-1	AE 006	1015	Yes	3.73 mg/m³	30%	9.1 %
PM_{10}	BS EN 23210	AE 060	1015	Yes	0.71 mg/m³	50%	3.8 %
$PM_{2.5}$	BS EN 23210	AE 060	1015	Yes	0.71 mg/m³	50%	3.9 %

On-Site Testing

Species	Standard Method	Scientifics Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Limit of Detection (LOD)	MU of Method +/- %	MU +/- %
NO_X	BS EN 14792	AE 008 / AE 015	1015	Yes	0.2 mg/m³	25%	12%
O_2	BS EN 14789	AE 007 / 015	1015	Yes	0.01%	10%	4.0%
H_2O	BS EN 14790	AE 004	1015	Yes	0.0008 %	10%	5.3%

EXECUTIVE SUMMARY

Analytical Methods

The following tables list the analytical methods employed together with the custody and archiving details:

Sampling Methods with Subsequent Analysis

Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	UKAS Accredited Analysis	Laboratory	Sample Archive Location	Archive Period
TPM	Gravimetric	AE 006	1015	Yes	Stockport	Stockport	3 months
PM_{10}	Gravimetric	AE 060	1015	Yes	Stockport	Stockport	3 months
$PM_{2.5}$	Gravimetric	AE 060	1015	Yes	Stockport	Stockport	3 months

On-Site Testing

Species	Analytical Technique	Analytical Procedure	UKAS Lab Number	MCERTS Accredited Analysis	Laboratory	Sample Archive Location	Span Gas
NO_X	Chemiluminsence	AE 008 / AE 015	1015	Yes	Stockport	N/A	800 ppm
O_2	Zirconia Cell	AE 007 / 015	1015	Yes	Stockport	N/A	11.29 %
H_2O	Gravimetric	AE 004	1015	Yes	Stockport	N/A	N/A

EXECUTIVE SUMMARY

Sampling Location

Sampling Plane Validation Criteria	Value	Units	Requirement	Compliance	Method
Lowest Differential Pressure	530	Pa	>= 5 Pa	Yes	BS EN 13284 - 1
Lowest Gas Velocity	35.27	m/s	-	-	-
Highest Gas Velocity	40.16	m/s	-	-	-
Ratio of Above	1.14	: 1	< 3 : 1	Yes	BS EN 13284 - 1
Mean Velocity	38.29	m/s	-	-	-
Angle of flow with regard to duct axis	10	^{o}	< 15^{o}	Yes	BS EN 13284 - 1
No local negative flow	-	-	-	Yes	BS EN 13284 - 1

Duct Characteristics

	Value	Units
Type	Circular	-
Depth	0.40	m
Width	-	m
Area	0.13	m^2
Port Depth	140	mm

Sampling Lines & Sample Points

	Isokinetic (CEN Methods)	Isokinetic (ISO Methods)	Non-Iso & Gases
Sample Port Size	4 inch BSP	-	2 inch Flange
Number Used	1	-	1
Orientation	Vertical	-	Vertical
Number Points / Line	1	-	1
Filtration	Out Stack	-	Out Stack
Filtration for TPM	Out Stack	-	-

Sampling Platform

General Platform Information	
Permanent / Temporary Platform	<1M Temporary
Inside / Outside	Outside

M1 Platform requirements	
Minimum Platform Area 5 m^2	Yes
Platform has 2 levels of handrails (approximately 0.5 m & 1.0 m high)	Yes
Platform has vertical base boards (approximately 0.25 m high)	Yes
Platform has removable chains / self closing gates at the top of ladders	Yes
Handrail / obstructions do not hamper insertion of sampling equipment	Yes
Depth of Platform = Minimum of 2m or Probe Length + 1m	Yes

Sampling Location / Platform Improvement Recommendations

The sampling location meets all the requirements as specified in EA Guidance Note M1.

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Reduced Particulate and PM10 & 2.5 Sampling Duartions

Due to the high dust loading in the stack, isokinetic sampling times had to be reduced as the filters were blocking.

Single Sampling Line

Only a single sampling line was available for isokinetic sampling so the number of sampling on points on the remaining line was doubled to meet the requirements of the standard.

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APPENDICES

STACK EMISSIONS MONITORING TEAM

Team Leader	Paul Adamczyk MCERTS Level 2, Technical Endorsements 1, 2, 3 & 4 MM 04 547
Team Leader	Craig Whittingham MCERTS Level 2, Technical Endorsements 1, 3 & 4 MM 05 669

TOTAL PARTICULATE MATTER SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	14:45 - 14:57 08 July 2010	98	3.7	-	307
Blank	-	9.5	-	-	-

Reference conditions are 273K, 101.3kPa, dry gas, 3% Oxygen.

Acetone Blank Value mg/l	Acceptable Value mg/l
5.00	10

ISOKINETIC SAMPLING EQUATIONS- RUN 1

TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	758.26
Stack static pressure, P_{static}	mm H_2O	20.39
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	759.76
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	12.5
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.02
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.149
Gas meter correction factor, Y_d		1.0608
Mean dry gas meter temperature, T_m		28.500
Mean pressure drop across orifice, ΔH	mmH_2O	20.640
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.143
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.1586
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		12.8
% oxygen reference condition		3
O_2 Reference Factor $O2\ Ref = \frac{21.0 - act\%O2}{21.0 - ref\%O2}$		0.46
$V_{mstd@X\%oxygen} = (V_{mstd})(O_{2\ Ref})$	m^3	0.0652
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0982 9.82
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.835
Mean of velocity heads, ΔP_{avg}	mm H_2O	62.33
Mean square root of velocity heads, $\sqrt{\Delta P}$		7.90
Mean stack gas temperature, T_s	°C	374
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{\sqrt{(M_s)(P_s)}}$	m/s	39.94

Molecular weight of dry gas, M_d		
CO_2	%	6.22
O_2	%	12.80
Total	%	19.02
N_2 (100 -Total)	%	80.98
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.51
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.38
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.13
$Q_a = (60)(A_s)(V_s)$	m^3/min	301.2
Total flow of stack gas, Q		
Conversion factor (K/mm.Hg)		0.3592
$Q_{std} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})}{(T_s) +273}$	Dry	114.6
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O2ref	52.08
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	127.03
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	3.90
Nozzle area, A_n	mm^2	11.72
Total sampling time, θ	min	12
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	111.6
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.0055
Mass collected in probe, M_p	g	0.0009
Total mass collected, M_n	g	0.0064
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	40.341
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	44.733
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	98.194
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		307.47

TOTAL PARTICULATE MATTER QUALITY ASSURANCE CHECKLIST

Leak Rate

Run	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable?
Run 1	13.17	0.1	0.1	-12	0.26	Yes

Isokineticity

Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	111.57	Yes

Acceptable Isokinetic rate 95 -115%

Blank Value

Run	Overall Blank Value mg/m^3	Daily Emission Limit Value mg/m^3	Acceptable Blank Value mg/m^3	Overall Blank Acceptable mg/m^3
Blank 1	9.51	-	-	Yes

Filters

Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-conditioning Filter Temperature °C	Post conditioning Filtration Temperature °C
Run 1	GF	47	386	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PM_{10} SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	15:38 - 15:50 08 July 2010	80	0.71	-	284

Reference conditions are 273K, 101.3kPa, dry gas, 3% Oxygen.

$PM_{2.5}$ SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	15:38 - 15:50 08 July 2010	74	0.71	-	264

Reference conditions are 273K, 101.3kPa, dry gas, 3% Oxygen.

ISOKINETIC SAMPLING EQUATIONS RUN 1

PM_{10} & $PM_{2.5}$

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	757.5
Stack static pressure, P_{static}	mm H_2O	1.5
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	757.6
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	-
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.02
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.40
Gas meter correction factor, Y_d		1.0608
Mean dry gas meter temperature, T_m		27.30
Mean pressure drop across orifice, ΔH	mmH_2	70.00
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.382
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.398
Vol. of gas metered at O_2 Ref. Cond., $V_{mstd@X\%O2}$		
Is the process burning hazardous waste? *(If yes, no favourable oxygen correction)*		No
% oxygen measured in gas stream, act%O_2		12.50
% oxygen reference condition		3
O_2 Reference Factor $O2\ Ref = \frac{21.0 - act\%O2}{21.0 - ref\%O2}$		0.47
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	0.181
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0982
	%	9.82
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		0.835
Mean of velocity heads, ΔP_{avg}	mm H_2O	62.33
Mean square root of velocity heads, $\sqrt{\Delta P}$		7.90
Mean stack gas temperature, T_s	°C	334
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{\sqrt{(M_s)(P_s)}}$	m/s	38.74

Molecular weight of dry gas, M_d		
CO_2		6.22
O_2		12.50
Total		18.72
N_2 (100 -Total)		81.28
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		29.49
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$		28.37
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	4.90
Nozzle area, A_n	mm^2	18.86
Total sampling time, θ	min	12.0
	%	106.2
Acceptable Isokinetic range 90% - 130%		Yes
Particulate Concentration, C_{PM10}		
Mass of particulate collected on PM_{10} filter, M_f	g	0.00101
Mass of particulate collected on $PM_{2.5}$ filter, M_f	g	0.01338
$C_{wet} = \frac{M_f}{V_{mstw}}$	mg/m³	36.17
$C_{dry} = \frac{M_f}{V_{mstd}}$	mg/m³	37.65
$C_{dry@X\%O2} = \frac{M_f}{V_{mstd@X\%oxygen}}$	mg/m³	79.72
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		284.28
Particulate Concentration, $C_{PM2.5}$		
Mass of particulate collected on filter, M_f		0.01338
$Cwet = \frac{Mf}{V_{mstw}}$	mg/m³	33.6335
$C_{dry} = \frac{M_f}{V_{mstd}}$	mg/m³	35.0039
$C_{dry@X\%O2} = \frac{M_f}{V_{mstd@X\%oxygen}}$	mg/m³	74.1259
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		264.33

PM_{10} & $PM_{2.5}$ QUALITY ASSURANCE CHECKLIST

Leak Rate

Run	Mean Sampling Rate litre/min	Pre-sampling Leak Rate litre/min	Post-sampling Leak Rate litre/min	Maximum Vacuum mm Hg	Acceptable Leak Rate litre/min	Leak Tests Acceptable?
Run 1	34.92	0	0	-14	0.70	Yes

Isokineticity

Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	Yes	Yes

Acceptable Isokinetic rate 90 -130%

Filters

Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-conditioning Filter Temperature °C	Post conditioning Filtration Temperature °C
Run 1	QF	50	334	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

COMBUSTION GASES SUMMARY

Test	Sampling Times	Concentration mg/m³	LOD mg/m³	Limit mg/m³	Emission Rate g/hr
NOx	18:41 - 19:41 08 July 2010	4409	2.05	-	13439

Test	Sampling Times	Concentration %	LOD %
O_2	18:41 - 19:41 08 July 2010	12.8	0.003

Reference conditions are 273K, 101.3kPa, dry gas, 3% Oxygen.

PRE-SAMPLING CALIBRATION DATA

Date	08 July 2010
Start Time	11:19
End Time	11:30

Cooler Temp. (°C)	1.7

(should be < 4°C)

Gas	Range (ppm)	Zero Reading at analyser	Span Reading at analyser	Zero Check at analyser	Zero Check down line	Span Check down line	Response Time (Secs)	Leak Rate %
NO	1000	0	800	0.03	0.3	798	25	-0.25
O2	25	0	11.29	0.02	0.03	11.33	15	0.35

POST-SAMPLING CALIBRATION DATA

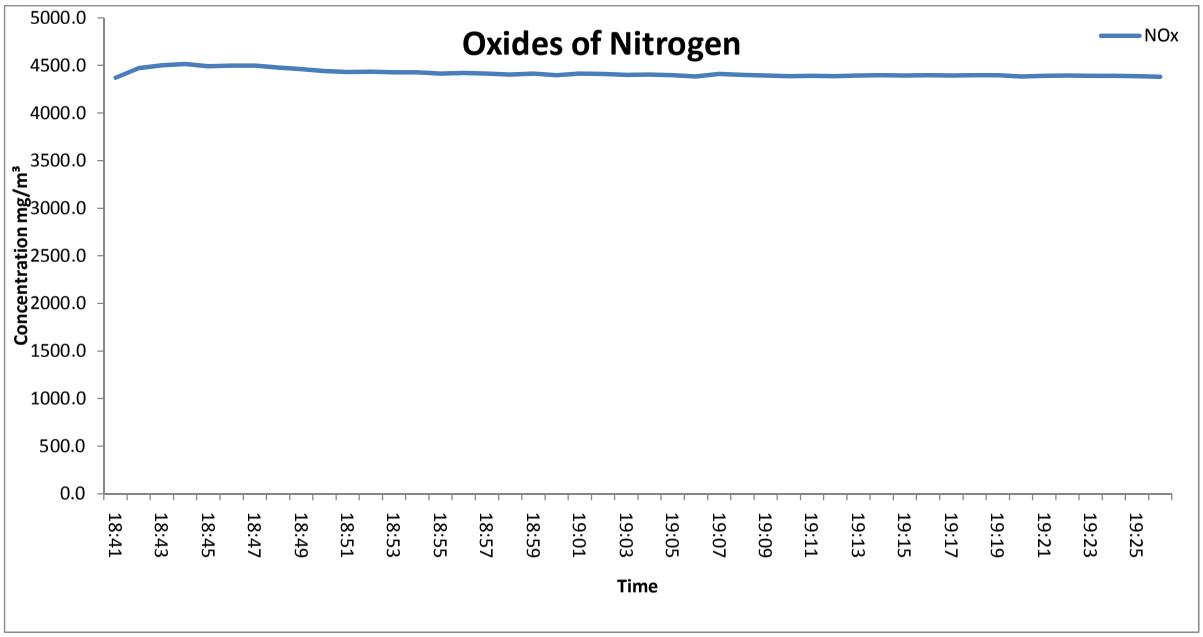
Date	08 July 2010
Start Time	19:58
End Time	20:10

Cooler Temp. (°C)	1.4

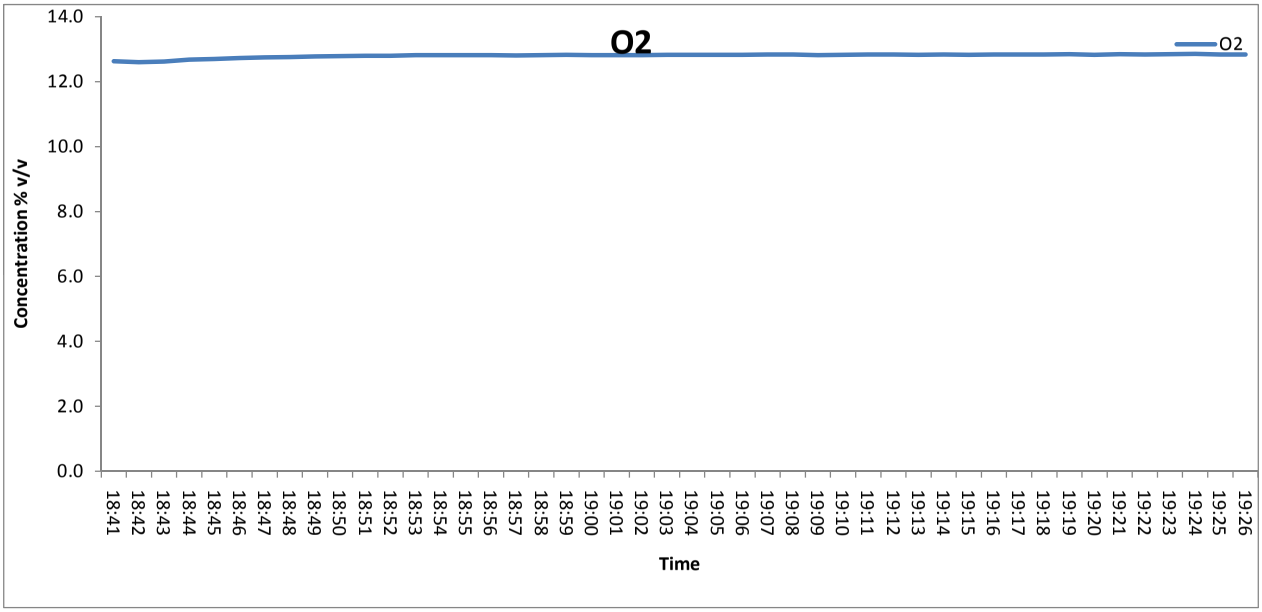
(should be < 4°C)

Gas	Zero Check down line	Span Check down line	Zero Drift (%)	Span Drift (%)
NO	0.08	795	-0.02	-0.38
O2	0.04	11.3	0.04	-0.27

OXIDES OF NITROGEN (as NO_2) EMISSIONS CHART



OXYGEN EMISSIONS CHART



PRELIMINARY STACK SURVEY

Stack Diameter / Depth, D	0.40	m
Stack Width, W	-	m
Stack Area, A	0.13	m^2
Average stack gas temperature	364	^oC
Pitot static pressure	0.2	kPa
Barometric Pressure	101.1	kPa
Pitot tube calibration coefficient, K_{pt}	0.84	-

Stack Gas Composition & Molecular Weights

Component	Molar Mass M	Density kg/m^3 p	Conc Dry % Vol	Dry Volume Fraction r	Dry Conc kg/m^3 pi	Conc Wet % Vol	Wet Volume Fraction r	Wet Conc kg/m^3 pi
CO_2	44	1.963059	15.800000	0.158000	0.310163	14.248850	0.142488	0.279713
O_2	32	1.427679	12.750000	0.127500	0.182029	11.498280	0.114983	0.164159
N_2	28	1.249219	71.450000	0.714500	0.892567	64.435462	0.644355	0.804940
H_2O	18	0.803070	-	-	-	9.817408	0.098174	0.078841

Where:
p = M / 22.41
p*i* = r x p

Calculation of Stack Gas Densities

Determinand	Result	Units
Dry Density (STP), P_{STD}	1.3848	kg/m^3
Wet Density (STP), P_{STW}	1.3277	kg/m^3
Dry Density (Actual), P_{Actual}	0.5935	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	0.569	kg/m^3

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	08 July 2010
Time of Survey	14:15 - 14:20
Velocity Measurement Device:	S - Type Pitot

Sampling Line A

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp ^oC	Velocity m/s	O_2 % Vol	Angle of Swirl ^{o}
1	0.02	60	588	364	37.2	-	10
2	0.06	64	627	364	38.4	-	10
3	0.10	68	666	364	39.6	-	10
4	0.14	65	637	364	38.7	-	10
5	0.18	68	666	364	39.6	-	10
6	0.22	70	686	364	40.2	-	10
7	0.26	66	647	364	39.0	-	10
8	0.30	62	608	364	37.8	-	10
9	0.34	60	588	364	37.2	-	10
10	0.38	54	529	364	35.3	-	10
Mean	-	64	624	364	38.3	-	

Sampling Line B

Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp ^oC	Velocity m/s	O_2 % Vol	Angle of Swirl ^{o}
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

PRELIMINARY STACK SURVEY (CONTINUED)

TRAVERSE 1 CONTINUED

Sampling Line C							
Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp °C	Velocity m/s	O_2 % Vol	Angle of Swirl °
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

Sampling Line D							
Traverse Point	Distance into duct (m)	ΔP pt mmH_2O	ΔP pt Pa	Temp °C	Velocity m/s	O_2 % Vol	Angle of Swirl °
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria

EA Technical Guidance Document (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	529.2	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	35.27	m/s	-	-
Highest Gas Velocity	40.16	m/s	-	-
Ratio of Above	1.14	-	< 3 : 1	Yes
Angle of flow with regard to duct axis	10	°	< 15°	Yes
No local negative flow	-	-	-	Yes

Other Sampling Method Criteria	Result	Units	Requirement	Compliant
Mean Velocity	38.29	m/s	-	-
Standard Deviation of Velocity from Mean	3.83	%	< 10%	Yes
Mean Oxygen	12.75	%	-	-
Standard Deviation of Oxygen from Mean	-	%	< 15%	-
Homogeneous flow stream / gas velocity	-	-	-	Yes

Where:

P_{STD} = sum of component concentrations, kg/m^3 (not including water vapour)

P_{STW} = (P_{STD} + p*i* of H_2O) / (1 + (p*i* of H_2O / 0.8036))

P_{Actual} = P_{STD} x (Ts / Ps) x (Pa / Ta)

$P_{ActualW}$ (at each sampling point) = P_{STW} x (Ts / Ps) x (Pa / Ta)

Calculation of Stack Gas Velocity, V

Velocity at Traverse Point, V = K_{pt} x (1-ε) * √(2 * ΔP_{pt} / $P_{ActualW}$)

Calculation based on BS 1042:Section 2.1:1983 (Section 7 - Velocity Computation)

Where:

K_{pt} = Pitot tube calibration coefficient

(1-ε) = Compressibility correction factor, assumed at a constant 0.998

Average Stack Gas Velocity, Va	**38.29**	m/s

PRELIMINARY STACK SURVEY (CONTINUED)

Calculation of Stack Gas Volumetric Flowrate, Q

Sampling plane reference conditions

Duct gas flow conditions	Actual	Reference	Units
Temperature	364	0	^{o}C
Total Pressure	101.3	101.3	kPa
Oxygen	13	3	%
Moisture	9.82	0.00	%

Gas Volumetric Flowrate	Result	Units
Gas Volumetric Flowrate (Actual), Q_{Actual}	17322	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	7424	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	6695	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	3048	m^3/hr

Where:

Q_{Actual} = Va x A x 3600

Q_{STP} = Q (Actual) x (Ts / Ta) x (Pa / Ps) x 3600

$Q_{STP,Dry}$ = Q (STP) / (100 - (100 / Ma)) x 3600

Q_{Ref} = Q (STP) x ((100 - Ma) / (100 - Ms)) x ((20.9 - O_2a) / (20.9 - O_2s))

Nomenclature:

Ts = Absolute Temperature, Standard Conditions, 273 K

Ps = Absolute Pressure, Standard Conditions, 101.3 kPa

Ta = Absolute Temperature, Actual Conditions, K

Pa = Absolute Pressure, Actual Conditions, kPa

Ma = Water vapour, Actual Conditions, % Vol

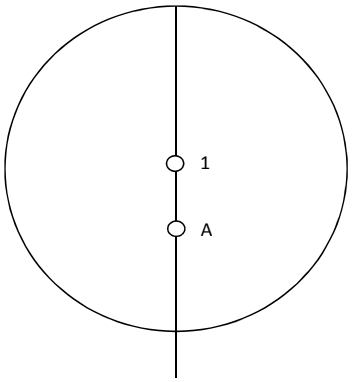
Ms = Water vapour, Reference Conditions, % Vol

O_2a = Oxygen, Actual Conditions, % Vol

O_2s = Oxygen, Reference Conditions, % Vol

STACK DIAGRAM

	Value	Units
Stack Depth	0.40	m
Stack Width	-	m
Area	0.13	m^2



Sampling Line

Non-Isokinetic Sampling

Sampling Point	Distance (% of Depth)	Distance into Stack	Units
A	30	0.12	m

Isokinetic Sampling CEN Methods

Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	50.0	0.20	10
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

APPENDIX 3 - Calibrateable Equipment Checklist & Calibration Gases

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	LAB 13 - 06	Horiba PG-250 Analyser	LAB 1240	Laboratory Balance	LAB 0001
Box Thermocouples	LAB 03 - 06	JCT JCC P-1 Cooler	LAB 0711	Tape Measure	LAB 08 - 04
Meter In Thermocouple	LAB 10 - 06A	MAK 10 Cooler	-	Stopwatch	LAB 1535
Meter Out Thermocouple	LAB 10 - 06B	FT-IR	-	Protractor	LAB 23 - 04
Control Box Timer	LAB 17 - 06	FT-IR Oven Box	-	Barometer	LAB 21 - 04
Oven Box	LAB 09 - 16	Bernath 3006 FID	-	Digital Micromanometer	LAB 01 - 04
Probe	LAB 11 - 13	Signal 3030 FID	-	Digital Temperature Meter	LAB 0651
Probe Thermocouple	LAB 1620	Servomex	-	Stack Thermocouple	-
Probe	-	JCT Heated Head Filter	-	Mass Flow Controller	-
Probe Thermocouple	-	Thermo FID	-	Mass Flow Control Box	-
S-Pitot	LAB 1310	Stackmaster	-	1m Heated Line (1)	-
L-Pitot	-	FTIR Heater Box for Heated Line	-	1m Heated Line (2)	-
Site Balance	LAB 14 - 08		-	1m Heated Line (3)	-
Last Impinger Arm	-		-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-		-	10m Heated Line (1)	-
Callipers	LAB 31 - 04		-	10m Heated Line (2)	-
Small DGM	LAB 1543		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	LAB 18 - 05
			-	20m Heated Line (2)	-

NOTE: If the equipment I.D is represented by a dash (-), then this piece of equipment has not been used for this test.

CALIBRATION GASES

Gas	Cylinder I.D. Number	Supplier	ppm	%	Analytical Tolerance +/- %
Oxygen	409	Cryoservice	-	11.29	2
Nitric Oxide	511	Cryoservice	800	-	2

All the above gases are traceable to ISO 17025.

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Limit of Detection	Leak	Uncollected Mass
	m^3	K	kPa	% by volume	% by volume	% by mass	%	mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2	0.5	1	0.1	0.243	-	-
as a %	1.53	0.66	0.49	1.00	0.78	N/A	0.76	N/A
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**N/A**

Run	Volume (STP)	Mass of particulate	O2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.06	6.4000	2.20	0.430	0.00	-
MU as mg/m^3	2.10	3.7331	1.20	0.430	0.01	**4.47**
MU as %	2.13	3.8017	-	0.438	0.01	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**8.93**	**mg/m^3**	**9.10**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)

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MEASUREMENT UNCERTAINTY BUDGET - PM 10

Run	Sampled Volume m^3	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**
Run 1	0.001	2	0.5	1	0.1	0.13	-
as a %	0.55	0.33	0.49	1.00	0.80	N/A	0.00
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m^3	Mass of particulate mg	O2 Correction -	Leak mg/m^3	Combined uncertainty
Run 1	984.78	5.5401	37.65	1.000	-
MU as mg/m^3	1.35	0.7051	0.00	0.000	**749.46**
MU as %	749.46	0.8845	0.00	0.000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**3.05**	**mg/m^3**	**3.83**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
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MEASUREMENT UNCERTAINTY BUDGET - PM 2.5

Run	Sampled Volume m^3	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**
Run 1	0.001	2	0.5	1	0.1	0.13	-
as a %	0.55	0.33	0.49	1.00	0.80	N/A	0.00
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP) m^3	Mass of particulate mg	O2 Correction -	Leak mg/m^3	Combined uncertainty
Run 1	915.66	5.5401	35.00	1.000	-
MU as mg/m^3	1.26	0.7051	0.00	0.000	**696.85**
MU as %	696.85	0.9513	-	0.000	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**2.88**	**mg/m^3**	**3.89**	**%**

(k is a coverage factor which gives a 95% confidence in the quoted figures)
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MEASUREMENT UNCERTAINTY BUDGET - MOISTURE

Run	Sampled Volume	Sampled Gas Temp	Sampled Gas Pressure	Sampled Gas Humidity	Oxygen Content	Leak
	m^3	K	kPa	% by volume	% by volume	%
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 2%**
Run 1	0.001	2	0.5	1	0.1	-
as a %	1.53	0.66	0.49	1.00	0.78	0.76
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Run	Volume (STP)	Mass Gained	O2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.06	12500.00	2.20	840.65	57.74	-
MU as % v/v	0.51	0.19	0.29	0.11	0.111	**0.64**
MU as %	2.13	0.80	1.22	0.44	0.46	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**1.28**	**% v/v**	**5.32**	**%**

APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXIDES OF NITROGEN

Limit value	-	mg/m^3
Measured concentration	4409.1	mg/m^3
Cal gas conc	1640	mg/m^3
Full Scale	2050	mg/m^3

Performance characteristics	Value	Units	specification	MU Met?
Response time	25	seconds	180	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60.00000001	minutes	-	-
Number of readings in measurement	60.00000001	-	-	-
Repeatability at zero	0.25	% full scale	<1 % range	Yes
Repeatability at span level	0.15	% full scale	<2 % range	Yes
Deviation from linearity	0.7	% of value	<2 % range	Yes
Zero drift	-0.022	% full scale	<2% range / 24hr	Yes
Span drift	-0.375	% full scale	<2% range/24hr	Yes
volume or pressure flow dependence	0.02	% of full scale/3 kPa	<2 % / 3 kPa	Yes
atmospheric pressure dependence	0.8	% of full scale/2 kPa	<3% / 2 kPa	Yes
ambient temperature dependence	0.01	% full scale/10K	<3% range / 10 K	Yes
dependence on voltage	0.1	% full scale/10V	< 0.1%vol /10 volt	Yes
losses in the line (leak)	-0.25	% of value	< 2% of value	Yes
Uncertainty of calibration gas	2	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	0.02
Standard deviation of repeatability at span level	urs	0.02
Lack of fit	ufit	8.28
Drift	u0dr	-0.59
volume or pressure flow dependence	uspres	0.01
atmopsheric pressure dependence	uapres	0.50
ambient temperature dependence	utemp	0.00
Dependence on voltage	uvolt	1.77
losses in the line (leak)	uleak	-6.38
Uncertainty of calibration gas	ucalib	18.94
Uncertainty in factor	uf	274.50

Measurement uncertainty (Concentration Measured)	4409.08	mg/m^3
Combined uncertainty	275.36	mg/m^3
Expanded uncertainty	550.72	mg/m^3

Expanded uncertainty expressed with a level of confidence of 95%	**-**	**% ELV**

Expanded uncertainty expressed with a level of confidence of 95%	**550.72**	**mg/m^3**

Expanded uncertainty expressed with a level of confidence of 95%	**12.49**	**% value**

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APPENDIX 4 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - OXYGEN

Reference	3	%vol
Measured concentration	12.81	%vol
Calibration gas	11.29	%vol
Full Scale	25	%vol

Performance characteristics	Value	Units	specification	MU Met?
Response time	15	seconds	< 200 s	Yes
Logger sampling interval	60	seconds	-	-
Measurement period	60.00000001	minutes	-	-
Number of readings in measurement	60.00000001	-	-	-
Repeatability at zero	0.015	% by volume	<0.2 % range	Yes
Repeatability at span level	0.014	% by volume	<0.4 % range	Yes
Deviation from linearity	0.13	% vol	<0.3 % volume	Yes
Zero drift (during measurement period)	0.04	% vol at zero level	<2% of volume / 24hr	Yes
Span drift (during measurement period)	-0.27	% vol at span level	<2% volume/24hr	Yes
volume or pressure flow dependence	0.02	% of fs / 10l/h	<1% range	Yes
atmospheric pressure dependence	0.80	% of fs/kPa	< 1.5 % range	Yes
ambient temperature dependence	0.01	% by volume /10K	<0.3% volume 10 K	Yes
Combined interference	0.14	% range	<2% range	Yes
Dependence on voltage	0.10	% by volume /10V	< 0.1%vol /10 volt	Yes
Losses in the line (leak)	0.35	% of value	< 2% of value	Yes
Uncertainty of calibration gas	2.00	% of value	< 2% of value	Yes

Performance characteristic	Uncertainty	Value of uncertainty quantity
Standard deviation of repeatability at zero	ur0	-
Standard deviation of repeatability at span level	urs	0.0018
Lack of fit	ufit	0.0751
Drift	u0dr	-0.1509
volume or pressure flow dependence	uspres	0.00003
atmospheric pressure dependence	uapres	0.0122
ambient temperature dependence	utemp	0.0005
Combined interference (from mcerts)	-	0.0808
dependence on voltage	uvolt	0.0862
losses in the line (leak)	uleak	0.0261
Uncertainty of calibration gas	ucalib	0.1479

Measurement uncertainty (Concentration Measured)	12.81	%vol
Combined uncertainty	0.26	%vol
% of value	1.99	%

Expanded uncertainty expressed with a level of confidence of 95%	**3.98**	**% of value**

Expanded uncertainty expressed with a level of confidence of 95%	**0.510**	**% vol**

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