STACK EMISSIONS MONITORING REPORT

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Cemex UK Materials Ltd Dowding Road Lincoln Lincolnshire LN3 4PQ

Permit:
Defra Process Guidance Note: PG 3/15 (12)

Release Point:
Coating Plant

Sampling Date(s):
19th September 2013

ESG Job Number:	LNO 11459
Report Date:	25th September 2013
Version:	1
Report By:	Johnathon Orley
MCERTS Number:	MM 08 983
MCERTS Level:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Report Approved By:	Mark Woodruff
MCERTS Number:	MM 03 164
Business Title:	MCERTS Level 2 - Team Leader
Technical Endorsements:	1, 2, 3 & 4
Signature:	

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EXECUTIVE SUMMARY

Stack Emissions Monitoring Objectives

Cemex UK Materials Ltd operates a roadstone coating process at Grimsby which is subject to Defra Process Guidance Note PG 3/15 (12), under the Environmental Permitting Regulations 2010.

Environmental Scientifics Group Limited were commissioned by Cemex UK Materials Ltd to carry out stack emissions monitoring to determine the release of prescribed pollutants from the following Plant under normal operating conditions.

The results of these tests shall be used to demonstrate compliance with a set of emission limit values for prescribed pollutants as specified in the Plant's Defra Process Guidance Note, PG 3/15 (12).

Plant

Coating Plant

Operator

Cemex UK Materials Ltd
Dowding Road
Lincoln
Lincolnshire
LN3 4PQ

Defra Process Guidance Note: PG 3/15 (12)

Stack Emissions Monitoring Test House

Environmental Scientifics Group Limited - Stockport Laboratory
Unit 5 Crown Industrial Estate
Kenwood Road
Stockport
SK5 6PH
UKAS and MCERTS Accreditation Number: 1015

Opinions and interpretations expressed herein are outside the scope of UKAS accreditation.
MCERTS accredited results will only be claimed where both the sampling and analytical stages are UKAS accredited.

EXECUTIVE SUMMARY

Emissions Summary

Parameter	Units	Result	Calculated Uncertainty +/-	Limit	MCERTS accredited result
Total Particulate Matter	mg/m³	11	0.88	50	✓
Particulate Emission Rate	g/hr	179	15	-	
Moisture	%	5.1	0.17	-	✓
Stack Gas Temperature	°C	74	-	-	
Stack Gas Velocity	m/s	20.6	-	-	
Gas Volumetric Flow Rate (Actual)	m³/hr	20940	-	-	✓
Gas Volumetric Flow Rate (STP, Wet)	m³/hr	16289	-	-	
Gas Volumetric Flow Rate (STP, Dry)	m³/hr	15197	-	-	
Gas Volumetric Flow Rate at Reference Conditions	m³/hr	16289	-	-	

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 flow data and not the above values.

Reference conditions are 273K, 101.3kPa without correction for water vapour

EXECUTIVE SUMMARY

Monitoring Times

Parameter	Sampling Date(s)	Sampling Times	Sampling Duration
Total Particulate Matter Run 1	19 September 2013	08:00 - 08:32	32 minutes
Total Particulate Matter Run 2	19 September 2013	08:56 - 09:28	32 minutes
Stack Gas Flow Rate & Temperature Run 1	19 September 2013	07:30	-

EXECUTIVE SUMMARY

Process Details

Parameter	Process Details
Description of process	Roadstone coating
Continuous or batch	Batch
Product Details	N/A
Part of batch to be monitored (if applicable)	N/A
Normal load, throughput or continuous rating	55 Tonnes / Hour
Fuel used during monitoring	Kerosine
Abatement	Bag Filter
Plume Appearance	Moderate steam plume visible

EXECUTIVE SUMMARY

Monitoring Methods

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

MONITORING METHODS						
Species	**Method** Standard Reference Method / Alternative Method	**ESG Technical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Method**	**Limit of Detection (LOD)**	**Calculated MU +/- %**
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	0.41 mg/m³	8.2 %
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	0.02%	3.2%
Flow Rate / Temp.	SRM - BS EN 13284-1	AE 122	1015	Yes	5 Pa	-

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 Lab Analysis**	**Analysis Lab (ESG or Subcontract)**	**Sample Archive Location**	**Archive Period**
TPM	Gravimetric	AE 106	1015	Yes	ESG Stockport	ESG Stockport	3 months

ON-SITE TESTING							
Species	**Analytical Technique**	**Analytical Procedure**	**UKAS Lab Number**	**MCERTS Accredited Analysis**	**Laboratory**	**Data Archive Location**	**Archive Period**
H_2O	Gravimetric	AE 105	1015	Yes	ESG Stockport	-	-

EXECUTIVE SUMMARY

Sampling Location

Sampling Plane Validation Criteria	Value	Units	Requirement	Compliant	Method
Lowest Differential Pressure	284	Pa	>= 5 Pa	Yes	BS EN 13284-1
Lowest Gas Velocity	20.3	m/s	-	-	-
Highest Gas Velocity	20.9	m/s	-	-	-
Ratio of Gas Velocities	1.03	: 1	< 3 : 1	Yes	BS EN 13284-1
Mean Velocity	20.6	m/s	-	-	-
Maximum angle of flow with regard to duct axis	5	^{o}	< 15^{o}	Yes	BS EN 13284-1
No local negative flow	Yes	-	-	Yes	BS EN 13284-1

Duct Characteristics

	Value	Units
Shape	Circular	-
Depth	0.60	m
Width	-	m
Area	0.28	m^2
Port Depth	90	mm

Sampling Lines & Sample Points

	Isokinetic (CEN Methods)	Isokinetic (ISO Methods)	Non-Iso & Gases
Sample port size	4 Inch BSP	-	-
Number of lines used	1	-	-
Number of points / line	4	-	-
Duct orientation	Vertical	-	-
Filtration for TPM	In Stack	-	-

Sampling Platform

General Platform Information	
Permanent / Temporary Platform / Ground level / Floor Level / Roof	Permanent
Inside / Outside	Outside

M1 Platform requirements	
Is there a sufficient working area so work can be performed in a compliant manner	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 Platform Improvement Recommendations (if applicable)

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

EXECUTIVE SUMMARY

Sampling & Analytical Method Deviations

Sampling Lines

Only one sampling line was available due to siezed port cap. The number of points were doubled along the remaining line

Nozzle Size

Due to the relatively high velocity in the stack a nozzle less than the required 6mm was used.

APPENDICES

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APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

MONITORING SCHEDULE

Species	Method Standard Reference Method / Alternative Method	ESG Technical Procedure	UKAS Lab Number	MCERTS Accredited Method	Number of Samples
TPM	SRM - BS EN 13284-1	AE 104	1015	Yes	2
H_2O	SRM - BS EN 14790	AE 105	1015	Yes	2
Flow Rate / Temp.	SRM - BS EN 13284-1	AE 122	1015	Yes	1

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

CALIBRATEABLE EQUIPMENT CHECKLIST

Extractive Sampling		Instrumental Analyser/s		Miscellaneous	
Equipment	**Equipment I.D.**	**Equipment**	**Equipment I.D.**	**Equipment**	**Equipment I.D.**
Control Box DGM	LNO 13-08	Horiba PG-250 Analyser	-	Laboratory Balance	LNO 27-01/27-02
Box Thermocouples	LNO 03-08	FT-IR	-	Tape Measure	LNO 24-JO
Meter In Thermocouple	LNO 03-08	FT-IR Oven Box	-	Stopwatch	LNO 17-JO
Meter Out Thermocouple	LNO 03-08	Bernath 3006 FID	-	Protractor	LNO 23-JO
Control Box Timer	LNO 17-08	Signal 3030 FID	-	Barometer	LNO 08-JO
Oven Box	-	Servomex	-	Digital Micromanometer	LNO 01-JO
Probe	LNO 11-22	JCT Heated Head Filter	-	Digital Temperature Meter	LNO 03-JO
Probe Thermocouple	LNO 10-22	Thermo FID	-	Stack Thermocouple	LNO 10-JO
Probe	-	Stackmaster	-	Mass Flow Controller	-
Probe Thermocouple	-	FTIR Heater Box for Heated Line	-	MFC Display module	-
S-Pitot	LNO 06-JO	Anemometer	-	1m Heated Line (1)	-
L-Pitot	-	Ecophysics NOx Analyser	-	1m Heated Line (2)	-
Site Balance	LNO 14-12	Chiller (JCT/MAK 10)	-	1m Heated Line (3)	-
Last Impinger Arm	-		-	5m Heated Line (1)	-
Dioxins Cond. Thermocouple	-		-	10m Heated Line (1)	-
Callipers	LNO 31-JO		-	10m Heated Line (2)	-
Small DGM	-		-	15m Heated Line (1)	-
Heater Controller	-		-	20m Heated Line (1)	-
Inclinometer (Swirl Device)	LNO 23-JO		-	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.

APPENDIX 1 - Monitoring Schedule, Calibration Checklist & Monitoring Team

STACK EMISSIONS MONITORING TEAM

Team Leader	Johnathon Orley MCERTS Level 2, Technical Endorsements 1, 2, 3 & 4 MM 08 983 MCERTS Expiry Date - Mar 2015 H&S Expiry Date - Nov 2013
Technician	Vic Johnson MCERTS Level 1, Technical Endorsement 1 MM 10 1085 MCERTS Expiry Date - Dec 2016 H&S Expiry Date - Sep 2015

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

TOTAL PARTICULATE MATTER SUMMARY

Parameter	Sampling Times	Concentration mg/m³	Uncertainty mg/m³	Limit mg/m³	Emission Rate g/hr
Run 1	08:00 - 08:32 19 September 2013	11	0.89	50	184
Run 2	08:56 - 09:28 19 September 2013	10	0.86	50	175
Blank	-	1.7	-	-	-

Reference conditions are 273K, 101.3kPa without correction for water vapour

Acetone Blank Value mg/l	Acceptable Value mg/l
2.0	10

FILTER INFORMATION

Samples

Test	Filter & Probe Rinse Number	Filter Start Weight g	Filter End Weight g	Mass Gained on Filter g	Probe Rinse Start Weight g	Probe Rinse End Weight g	Mass Gained on Probe g	Combined Total Mass Gained g
Run 1	G0603	0.10571	0.10731	0.00160	191.71490	191.71980	0.00490	0.00650
Run 2	G0604	0.11361	0.11629	0.00268	174.32420	174.32760	0.00340	0.00608

If total mass gained is less than the LOD then the LOD is reported

Blanks

Test	Filter & Probe Number	Filter Start Weight g	Filter End Weight g	Mass Gained Filter g	Probe Start Weight g	Probe End Weight g	Mass Gained Probe g	Combined Total Mass Gained g
Run 1	G0602	0.11255	0.11234	-0.00021	179.02630	179.02750	0.00120	0.00099

If total mass gained is less than the LOD then the LOD is reported

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 1 — TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	750.01
Stack static pressure, P_{static}	mm H_2O	16.32
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	751.21
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	16.4
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.020
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.745
Gas meter correction factor, Y_d		0.8100
Mean dry gas meter temperature, T_m		19.000
Mean pressure drop across orifice, ΔH	mmH_2O	42.059
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.559
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.5795
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		21.0
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$	%	0.0353 3.53
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		.84
Mean of velocity heads, ΔP_{avg}	mm H_2O	31.00
Mean square root of velocity heads, $\sqrt{\Delta P}$		5.57
Mean stack gas temperature, T_s	°C	80
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	21.00

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	21.00
Total	%	21.03
N_2 (100 -Total)	%	78.97
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.46
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.28
$Q_a = (60)(A_s)(V_s)$	m³/min	356.3
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	263.1
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	272.74
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	4.90
Nozzle area, A_n	mm^2	18.86
Total sampling time, θ	min	32
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	99.5
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00160
Mass collected in probe, M_p	g	0.00490
Total mass collected, M_n	g	0.00650
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m³	11.217
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m³	11.627
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m³	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		183.56

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

ISOKINETIC SAMPLING EQUATIONS - RUN 2 — TPM

Absolute pressure of stack gas, P_s		
Barometric pressure, P_b	mm Hg	750.01
Stack static pressure, P_{static}	mm H_2O	16.32
$P_s = \frac{P_b + (P_{static})}{13.6}$	mm Hg	751.21
Vol. of water vapour collected, V_{wstd}		
Moisture trap weight increase,Vlc	g	32.2
$V_{wstd} = (0.001246)(V_{lc})$	m^3	0.040
Volume of gas metered dry, V_{mstd}		
Volume of gas sample through gas meter, V_m		0.751
Gas meter correction factor, Y_d		0.8100
Mean dry gas meter temperature, T_m		21.722
Mean pressure drop across orifice, ΔH	mmH_2O	46.329
$V_{mstd} = \frac{(0.3592)(V_m)(P_b+(\Delta H/13.6))(Y_d)}{T_m + 273}$		0.559
Volume of gas metered wet, V_{mstw}		
$V_{mstw} = V_{mstd} + V_{wstd}$	m^3	0.5987
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		21
% oxygen reference condition		21
O_2 Reference Factor O_2 Ref $= \frac{21.0 - act\%O_2}{21.0 - ref\%O_2}$		No O2 Ref
$V_{mstd@X\%oxygen} = (V_{mstd})\ (O_{2\ Ref})$	m^3	No O2 Ref
Moisture content, B_{wo}		
$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}}$		0.0670
	%	6.70
Moisture by FTIR	%	-
Velocity of stack gas, V_s		
Pitot tube velocity constant, K_p		34.97
Velocity pressure coefficient, C_p		.84
Mean of velocity heads, ΔP_{avg}	mm H_2O	33.56
Mean square root of velocity heads, $\sqrt{\Delta P}$		5.79
Mean stack gas temperature, T_s	°C	77
$V_s = \frac{(K_p)(C_p)(\sqrt{\Delta P})(\sqrt{(T_s + 273)})}{(M_s)(P_s)}$	m/s	21.89

Molecular weight of dry gas, M_d		
CO_2	%	0.03
O_2	%	21.00
Total	%	21.03
N_2 (100 -Total)	%	78.97
$M_d = 0.44(\%CO_2)+0.32(\%O_2)+0.28(\%N_2)$		28.84
Molecular weight of wet gas, M_s		
$M_s = M_d(1 - B_{wo}) + 18(B_{wo})$	g/gmol	28.12
Actual flow of stack gas, Q_a		
Area of stack, A_s	m^2	0.28
$Q_a = (60)(A_s)(V_s)$	m^3/min	371.5
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	267.5
$Q_{stdO2} = \frac{(Q_a)P_s(0.3592)(1-B_{wo})(O_2REF)}{(T_s) +273}$	@O_2ref	No O2 Ref
$Q_{stw} = \frac{(Q_a)P_s(0.3592)}{(T_s) +273}$	Wet	286.70
Percent isokinetic, %I		
Nozzle diameter, D_n	mm	4.90
Nozzle area, A_n	mm^2	18.86
Total sampling time, θ	min	32
$\%I = \frac{(4.6398E6)(T_s+273)(V_{mstd})}{(P_s)(V_s)(A_n)(\theta)(1-B_{wo})}$	%	97.8
Acceptable isokinetic range 95% to 115%		Yes
Particulate Concentration, C		
Mass collected on filter, M_f	g	0.00268
Mass collected in probe, M_p	g	0.00340
Total mass collected, M_n	g	0.00608
$C_{wet} = \frac{M_n}{V_{mstw}}$	mg/m^3	10.16
$C_{dry} = \frac{M_n}{V_{mstd}}$	mg/m^3	10.88
$C_{dry@X\%O2} = \frac{M_n}{V_{mstd@X\%oxygen}}$	mg/m^3	No O2 Ref
Particulate Emission Rates, E		
$E = [(C_{wet})(Q_{stw})(60)] / 1000$		174.69

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

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	18.9	0.20	0.20	-304.8	0.38	Yes
Run 2	19.0	0.20	0.22	-304.8	0.38	Yes

Isokineticity

Run	Isokinetic Variation %	Acceptable Isokineticity
Run 1	99.5	Yes
Run 2	97.8	Yes

Acceptable isokinetic range 95% to 115%

Balance Uncertainty

Run	Result mg/m³	5% ELV mg/m³	LOD < 5% ELV
Run 1	0.41	2.5	Yes
Run 2	0.40	2.5	Yes

The above is based on both the Filter and rinse uncertainty

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	1.68	50	5.0	Yes

Filters

Run	Filter Material	Filter Size mm	Max Filtration Temperature °C	Pre-use Filter Conditioning Temperature °C	Post-use Filter Conditioning Temperature °C
Run 1	GF	47	84	180	160
Run 2	GF	47	80	180	160

GF = Glass Fibre

QF = Quartz Fibre

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

MOISTURE CALCULATIONS

Moisture Determination - Isokinetic

Test Number	Sampling Time and Date	Start Weight kg	End Weight kg	Total gain kg	Concentration %	LOD %	Uncertainty %
Run 1	08:00 - 08:32 19 September 2013	3.9630	3.9794	0.0164	3.5	0.021	3.2
Run 2	08:56 - 09:28 19 September 2013	3.9794	4.0116	0.0322	6.7	0.021	3.0

Moisture Quality Assurance

Test Number	Sampling Duration mins	Total Volume Sampled l	Sampling Rate l/min	Start Leak Rate l/min	End Leak Rate l/min	Acceptable Leak Rate l/min	Leak Tests Acceptable?
Run 1	32	579	18.9	0.20	0.20	0.38	Yes
Run 2	32	599	19.0	0.20	0.22	0.38	Yes

PRELIMINARY STACK SURVEY

Stack Characteristics

Stack Diameter / Depth, D	0.60	m
Stack Width, W	-	m
Stack Area, A	0.28	m^2
Average stack gas temperature	74	^oC
Stack static pressure	0.16	kPa
Barometric Pressure	100	kPa
Pitot tube calibration coefficient, K_{pt}	0.85	-

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	0.030000	0.000300	0.000589	0.028466	0.000285	0.000559
O_2	32	1.427679	21.0	0.210000	0.299813	19.926086	0.199261	0.284481
N_2	28	1.249219	78.970000	0.789700	0.986508	74.931572	0.749316	0.936060
H_2O	18	0.803070	-	-	-	5.113876	0.051139	0.041068

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

Calculation of Stack Gas Densities

Determinand	Result	Units
Dry Density (STP), P_{STD}	1.2869	kg/m^3
Wet Density (STP), P_{STW}	1.2622	kg/m^3
Dry Density (Actual), P_{Actual}	1.0011	kg/m^3
Average Wet Density (Actual), $P_{ActualW}$	0.982	kg/m^3

Where:

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

$P_{STW} = (P_{STD} + pi \text{ of } H_2O) / (1 + (pi \text{ of } H_2O / 0.8036))$

$P_{Actual} = P_{STD} \times (Ts / Ps) \times (Pa / Ta)$

$P_{ActualW} = P_{STW} \times (Ts / Ps) \times (Pa / Ta)$

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY

TRAVERSE 1

Date of Survey	19 September 2013
Time of Survey	07:30
Velocity Measurement Device:	S-Type

Sampling Line A							
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	0.03	30	294	74	20.60	-	5
2	0.09	29	284	74	20.26	-	5
3	0.15	30	294	74	20.60	-	0
4	0.21	30	294	74	20.60	-	0
5	0.27	31	304	74	20.95	-	0
6	0.33	30	294	74	20.60	-	0
7	0.39	30	294	74	20.60	-	0
8	0.45	30	294	74	20.60	-	0
9	0.51	29	284	74	20.26	-	0
10	0.57	30	294	74	20.60	-	0
Mean	-	30	293	74	20.57	-	

Sampling Line B							
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	-	-	-	-	-	-	

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

PRELIMINARY STACK SURVEY (CONTINUED)

Sampling Plane Validation Criteria

EA Technical Guidance Note (Monitoring) M1	Result	Units	Requirement	Compliant
Lowest Differential Pressure	284.2	Pa	>= 5 Pa	Yes
Lowest Gas Velocity	20.3	m/s	-	-
Highest Gas Velocity	20.9	m/s	-	-
Ratio of Gas Velocities	1.03	-	< 3 : 1	Yes
Maximum angle of flow with regard to duct axis	5	^{o}	< 15^{o}	Yes
No local negative flow	Yes	-	-	Yes

Other Sampling Method Criteria	Result	Units	Requirement	Compliant
Mean Velocity	20.6	m/s	-	-
Standard Deviation of Velocity from Mean	0.95	%	< 10%	Yes
Mean Oxygen	-	%	-	-
Standard Deviation of Oxygen from Mean	-	%	< 15%	-
Homogeneous flow stream / gas velocity	-	-	-	Yes

Calculation of Stack Gas Velocity, V

Velocity at Traverse Point, $V = K_{pt} \times (1-\varepsilon) * \sqrt{(2 * \Delta P_{pt} / P_{ActualW})}$

Where:

K_{pt} = Pitot tube calibration coefficient

$(1-\varepsilon)$ = Compressibility correction factor, assumed at a constant 0.998

Average Stack Gas Velocity, Va **20.6** m/s

Calculation of Stack Gas Volumetric Flowrate, Q

Duct gas flow conditions	Actual	Reference	Units
Temperature	74	0	^{o}C
Total Pressure	100.16	101.3	kPa
Oxygen	21.0	21	%
Moisture	6.70	6.70	%

Gas Volumetric Flowrate	Result	Units
Average Stack Gas Velocity (Va)	20.6	m/s
Stack Area (A)	0.28	m^2
Gas Volumetric Flowrate (Actual), Q_{Actual}	20940	m^3/hr
Gas Volumetric Flowrate (STP, Wet), Q_{STP}	16289	m^3/hr
Gas Volumetric Flowrate (STP, Dry), $Q_{STP,Dry}$	15197	m^3/hr
Gas Volumetric Flowrate (REF), Q_{Ref}	16289	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

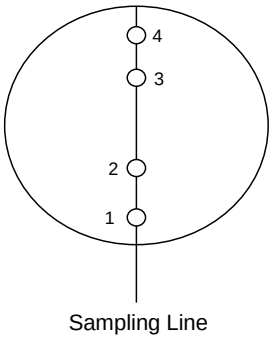
O_2a = Oxygen, Actual Conditions, % Vol

O_2s = Oxygen, Reference Conditions, % Vol

APPENDIX 2 - Summaries, Calculations, Raw Data and Charts

STACK DIAGRAM

	Value	Units
Stack Depth	0.60	m
Stack Width	-	m
Area	0.28	m^2



- Isokinetic sampling point
- Isokinetic sampling points not used
- Non Isokinetic/Gases sampling point

Non-Isokinetic Sampling

Sampling Point	Distance (% of Depth)	Distance into Stack	Units
-	-	-	-

Isokinetic Sampling CEN Methods

Sampling Point	Distance (% of Depth)	Distance into Stack (m)	Swirl °
1	8.3	0.05	5
2	25.0	0.15	0
3	75.0	0.45	0
4	91.7	0.55	0
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-
-	-	-	-

SAMPLING LOCATION

APPENDIX 3 - Measurement Uncertainty Budget Calculations

MEASUREMENT UNCERTAINTY BUDGET - TOTAL PARTICULATE MATTER

Run	Sampled Volume m³	Sampled Gas Temp K	Sampled Gas Pressure kPa	Sampled Gas Humidity % by volume	Oxygen Content % by volume	Limit of Detection % by mass	Leak %	Uncollected Mass mg
MU required	**≤ 2%**	**≤ 2%**	**≤ 1%**	**≤ 1%**	**≤ 10%**	**≤ 5% of ELV**	**≤ 2%**	**≤ 10% of ELV**
Run 1	0.001	2.0	0.50	1.0	N/A	0.24	-	-
as a %	0.17	0.68	0.50	1.00	N/A	0.83	1.06	0.002
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**
Run 2	0.001	2.0	0.50	1.00	N/A	0.24	-	-
as a %	0.17	0.68	0.50	1.00	N/A	0.80	1.16	0.002
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**	**Yes**	**Yes**

Run	Volume (STP) m³	Mass of particulate mg	O_2 Correction -	Leak mg/m³	Uncollected Mass mg	Combined uncertainty
Run 1	0.54	6.5000	1.00	0.069	0.0006	-
MU as mg/m^3	0.15	0.4142	-	0.069	0.0010	**0.45**
MU as %	1.32	3.6923	-	0.612	0.0088	-
Run 2	0.55	6.0800	1.00	0.068	0.0006	-
MU as mg/m^3	0.13	0.4009	-	0.068	0.0010	**0.43**
MU as %	1.3	3.9474	-	0.668	0.0094	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.89**	**mg/m³**	**7.94**	**%**

R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.86**	**mg/m³**	**8.43**	**%**

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

Developed for the STA by R Robinson, NPL

APPENDIX 3 - Measurement Uncertainty Budget Calculations

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	0.50	1.0	N/A	-
as a %	0.17	0.68	0.50	1.00	N/A	1.06
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**
Run 2	0.001	2.0	0.50	1.0	N/A	-
as a %	0.17	0.68	0.50	1.00	N/A	1.16
compliant?	**Yes**	**Yes**	**Yes**	**Yes**	**N/A**	**Yes**

Run	Volume (STP)	Mass Gained	O_2 Correction	Leak	Uncollected Mass	Combined uncertainty
	m^3	mg	-	mg/m^3	mg	
Run 1	0.54	16400.00	1.00	173.29	57.74	-
MU as % v/v	0.05	0.02	-	0.02	0.013	**0.06**
MU as %	1.32	0.61	-	0.61	0.35	-
Run 2	0.55	32200.00	1.00	359.37	57.74	-
MU as % v/v	0.09	0.02	-	0.05	0.01	**0.10**
MU as %	1.32	0.31	-	0.67	0.18	-

R1 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.12**	**% v/v**	**3.24**	**%**

R2 - Uncertainty expressed at a 95% confidence level (where k = 2)	**0.21**	**% v/v**	**3.05**	**%**

END OF REPORT